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16 OCT 1956

TROPICAL AGRICULTURE

HE JOURNAL OF THE IMPERIAL COLLEGE OF TROPICAL AGRICULTURE

THE IMPERIAL COLLEGE OF TROPICAL AGRICULTURE

Via colendi haud facilis

Vol. 31 - 1954

Published
on behalf of the College by
BUTTERWORTHS SCIENTIFIC PUBLICATIONS
88 Kingsway, London, W.C.2

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Printed in Great Britain by R. J. Acford Ltd., Chichester, Sussex.

Editorial

The appearance of *Tropical Agriculture* in a new format has already been heralded in our previous issue, and the advantages of publishing in the United Kingdom, which we hope will be appreciated by our readers, has been explained. This journal, which was founded in 1924, is still the only one in English which professes to deal with the agriculture of the tropics, and of the tropics only, as a whole. It is the hope of the Governing Body of the Imperial College of Tropical Agriculture that it will, under the new arrangements, be able to live more fully up to that profession. Of the increase in the subscription rate, it can only be said that it is regrettable but necessary. We hope to put before our subscribers articles of a quality which they will consider worth having at the price.

* * *

Many of our readers, who might be interested, may not yet have heard of the formation of the 'Association pour l'Étude Taxonomique de la Flore d'Afrique Tropicale'. This Association offers various facilities for the correlation of the work of botanists in Africa which they would be unwise to miss. It has also launched a project for an up-to-date vegetation map of the whole of Tropical Africa. It held its first conference at Brussels in 1951 and its second at Oxford in 1953. This must be almost unique among societies in that membership involves no subscription. Further information may be obtained from the Hon. Secretary, Mr. J. P. M. Brenan, The Herbarium, Royal Botanic Gardens, Kew, Surrey, England.

* * *

We are pleased to welcome a new contemporary, the Journal of the West African Institute for Oil Palm Research, of which the first number appeared in September 1953. Copies can be purchased from the Director of the Institute, Benin, Nigeria, or from the Crown Agents for the Colonies at 2s. 6d. It is stated that at present it will not be possible to publish the Journal at regular intervals, but that it is hoped to publish at least two numbers a year. The first number contains some authoritative articles on oil palm agronomy, diseases, and pollination. This will be an important publication not only for those concerned with oil palms, but also in countries

where other palms such as the coconut and date palm are important, for there is much in common between the botanical and agricultural problems of all palm crops.

* * *

We have been asked to draw attention to the International Code of Nomenclature for Cultivated Plants adopted at the Thirteenth International Horticultural Congress held in 1952. This code is of course supplementary to the International Code of Botanical Nomenclature which governs botanical (Latin) names for cultivated plants, and provides guidance for those who have to name new varieties and horticultural forms. Since a large part of the plant-breeding work carried out in the tropics involves the production of new plants, attention to such guidance is of importance if chaos in naming is to be avoided. Copies of the Code are obtainable from the Royal Horticultural Society, Vincent Square, London S.W.1, price 1/-, postage 3d.

Agricultural Policy in Colonial Territories

An Address delivered to the Colonial Office Conference of Directors of Agriculture at Wye 9th September 1953

PROFESSOR SIR FRANK ENGLEDOW
School of Agriculture, Cambridge University

Agricultural policy has a confusing diversity of meanings. This is illustrated by the very different kinds of action taken to assist or regulate national agriculture. Consideration of past action is a good way of approaching the question of agricultural policy in the present day, which will be treated at first generally and not in the limited reference of British colonial territories.

KINDS OF AGRICULTURAL POLICY

Relief of temporary agricultural distress, though a crude form of policy, has been not uncommon. In the United Kingdom, from the repeal of the Corn Laws in 1846, such agricultural policy as there was mostly took the form of reliefs and supports: between the two great wars there were steps like de-rating of agricultural land and the sugar subsidy.

Wheat export bounties were used to prop up agriculture in Australia and France in the 1930's.

Short-term production plans, with quantitative objectives, are a second familiar kind of agricultural policy. War or preparation for it or its economic after-effects, have now made these familiar. They have been implemented with price inducement, exhortation and varying degrees of compulsion according to the regime concerned.

In Germany, Italy and Japan efforts were made before War II to attain high self-sufficiency in food supply. From 1940 to the end of War II the United Kingdom used very carefully worked out and highly successful food production plans.

Currently, every efficiently administered country has adopted food production plans, usually of 4–5 years duration. Continuing and comprehensive support or protection for agricultural producers is the third category of policy here distinguished.

Standing limitations of imports of agricultural commodities have been and remain an important instrument for many countries.

In the U.S.A. the Agricultural Adjustment Act of 1938 had as one purpose, ' to regulate inter-State and foreign commerce in cotton, wheat, corn, tobacco and rice to the extent necessary to provide an orderly, adequate and balanced flow of such commodities in inter-State and foreign commerce through the storage of reserve supplies, loans, marketing quotas, assisting farmers to obtain, insofar as practicable, parity prices for such commodities and parity of income, and assisting consumers to obtain an adequate and steady supply of such commodities at fair prices '.*

* *U.S. Agric. Handbook, No.* 49 (1953) p. 17.

Long-term policies deriving from some general objective—political, social or economic—are the fourth category.

It is commonly reckoned that in the nineteenth century some European countries aimed at maintaining a big population of peasant farmers to ensure military strength and, it may be as they thought, political and social stability. This favouring of small-scale farming checked the spread of machinery on the land and involved relatively high costs of home produced foods, which burden the town populations had to bear.

In the Scottish Highlands, land settlement and other steps to stop the decline of a distinctive population, have been carried on for many years.

Switzerland, after several years of public discussion and contention, approved by referendum on 30 March 1952, a measure for the promotion of agriculture and safeguarding of the farming community. The expressed purpose was to maintain a healthy farming community in about the present proportion to the general population. A succession of measures towards this same end goes back to 1893. Subsidies and tariff covers are among the steps involved.

The U.S.A. offers the outstanding case in the free world of this general-objective type of policy. The aim of the Homestead Act of 1862 was to encourage the 'family farm', and this conception has greatly influenced their agricultural legislation. In the preface to the Soil Conservation Acts 1935–36, '. . . it is declared to be the policy of Congress to provide permanently for the control and prevention of soil erosion and thereby to preserve national resources, control floods, relieve unemployment . . . *etc*'*. The Secretary of Agriculture is empowered to apply measures under the Act on a national basis if any States prove reluctant to pass the necessary legislation. Financial aid is provided to various agencies and to farmers.

HISTORICAL INFERENCES ON AGRICULTURAL POLICY

These few examples illustrate aspects of a complex history of measures, all broadly describable as agricultural policy. In the light of the full history the following observations are made:

(*a*) History shows the rarity of anything resembling comprehensive, reasoned policy for a country's agriculture—there must be inherent difficulties.

(*b*) Emergency and other short-term plans may injure the long-term interest, *e.g.* condition of the land.

(*c*) The length of the production period of agricultural commodities, especially livestock, makes abrupt short-term changes in national policy undesirable.

(*d*) With cash commodities, stability of price and market may count more with the producer than price level. This often proves to be the essence of claims unreasonably but not uncommonly made by the agricultural community for a 'permanent' agricultural policy.

(*e*) Governments are specially afraid of long-term commitments to agriculture because of the unpredictability of output and therefore of price. Some short-term guarantees even have been highly embarrassing to Governments, cotton and butter supplying recent examples.

* *U.S. Agric. Handbook, No.* 49 (1953) p. 1.

(*f*) Policies for agriculture have often been made without due regard to the rest of the national economy.

(*g*) An agricultural policy usually gives varying satisfaction to different sections of the agricultural community: the best organized are apt to get the best terms.

(*h*) Policy in the sense of reasoned, continuing purpose, is apt to be confused with means for implementing policy. Thus education and research, credit facilities, price-fixing arrangements, marketing re-organization and other means for assisting agriculture, have been confused with motives. The 1947 Agricultural Act in the United Kingdom, which offers a highly effective means of controlling policy, is often mis-described as an agricultural policy.

(*j*) Plans in the form of quantitative objectives for agricultural production are also wrongly accepted as policy. In the United Kingdom the 1947–52 and the 1952–56 production plans have often been described as policy.

(*k*) Plans not deriving from reasoned policy may be biologically, economically or otherwise dangerous: policy without production plans may be only sterile theory.

(*l*) Both planning and planners can be abused and often deserve to be. A not uncommon failing is to assume that the chief factors in agricultural production will remain as at the time of planning, or to be over-confident in predicting the degree of change in them.

(*m*) Production plans must be fairly rigid in the short term, but flexibility is essential for the policy behind them, so that it may be suitably applied over the long term whatever the changes of circumstance.

(*n*) Zeal for efficiency of the national agriculture may result in policy proposals involving undue coercion or administrative cost.

In the light of these observations it is inferred that any territorial agricultural policy should be:

Conducive to the general long-term interest.
Continuous but not unalterable in purpose.
Adaptable to changing circumstance in its application.
Accompanied when necessary and practicable by quantitative plans which are duly revised but not abruptly altered.
Simple in essence.

PRINCIPLES FOR AGRICULTURAL POLICY

An agricultural policy with these desirable characteristics must rest on principles or guiding rules deriving from study of the primary factors. The branches of this study are: economic, strategic, biologic, sociological, nutritional and agricultural. Some incompatibility among guiding rules from these several branches is inevitable. Decision on policy must be with Government, according to the circumstances of the time, but principles should be available for their consideration.

Strategy and economics, though branches for expert study, have aspects on which agricultural advice is essential. In primarily agricultural communities, especially those dominated by subsistence farming, agriculture and the general economy are virtually one and the same.

Nutritional science, duly tempered by thought for human predilection, can specify the quantities and kinds of food that should be available in any territory. It would not be necessary to go far back into history to find prescriptions, particularly for milk and other protective foods, which the available territorial resources could not possibly meet by purchase and home production. There is an obvious way of avoiding harmful unpracticality of this kind.

A high degree of self-sufficiency in food supply is probably desirable in most colonial territories: the physical possibility of attaining it is mostly an agricultural issue, but its desirability a wider question. Self-sufficiency for a group, rather than for individual territories, may be the more appropriate aim, for instance, in the West Indies or West Africa.

Sociology in the present context is the study of human society, its behaviour, economic activities, culture, well-being and ethics. That there must arise from social considerations many principles proper to the formulation of agricultural policy, may seem obvious. Finding them is hindered by the intrusion of sentiment and lack of authentic evidence. Members of the Colonial Agricultural Service would be unwise to set themselves up as sociologists, but modesty would be surpassed if they disclaimed any knowledge of the 'behaviour, economic activities, culture and well-being' of colonial populations.

Some important complex social problems arise in shaping agricultural policy. One step indispensable to their solution is an amplification of the surveys of community and household agricultural economy. Excellent work already done, largely by District and Provincial Agricultural Officers as an 'additional' duty, has evolved methods and shown possibilities. The 'sample' survey developed by J. R. H. Shaul and his colleagues in Southern Rhodesia has given considerable precision to this kind of enquiry, but the need in colonial territories can only be met by more staff.

In addition to natural population changes, arranged movement, if feasible, may in special circumstances be agriculturally desirable. Land tenure, size of holding, social and ceremonial use of livestock, introduction of mechanical power and co-operative organization, are other familiar issues in which sociology and agriculture are fused together. One other matter should be mentioned—the absentee land holder. In some territories there are areas which support themselves largely by short-term labour emigration. Intermittent absence of a considerable proportion of the adult males is believed to be bad, both for the land and socially. Only in one case, so far, has it been attempted to devise policy in this matter.

POLICY PRINCIPLES FROM AGRICULTURAL SCIENCE AND EXPERIENCE

Advice from the agricultural side is needed, as already explained, for all other approaches or branches of study concerned with principles for agricultural policy, but agriculture's chief task is to seek what must be called the basic principles, namely, those concerned with the unalterable factors which influence the production of food. This allows of no separation of agriculture proper from veterinary science and forestry, or of science from practical knowledge and experience, and agriculture must stand here as the short name for all these associated interests.

Possibilities of production from the land are primarily governed by unalterable physical factors—soil, topography, climate. The partially controllable factors, including man, natural vegetation and fauna, which also influence the agricultural use of land, are themselves affected by the physical factors. It is the well recognized though only slightly understood interplay between all these factors, *e.g.* rainfall and temperature, and not each factor by itself, with which agriculture has to reckon. To yield a satisfactory and continuing return for labour, agricultural use of land must conform with the inherent circumstances, that is, the primary physical factors, and be conservative of natural resources. The principles for policy deriving from agricultural science and experience may therefore consist of reasoned conclusions under three headings:

(*a*) Environment regions.
(*b*) Conservation of natural resources.
(*c*) Farming systems.

ENVIRONMENT REGIONS

The foundation of that part of policy which agricultural experience and science has to provide is knowledge of the primary factors—soil, topography, climate, vegetation. These, in varying associations, mark out a territory into environmental (or natural or ecological) regions. A ' region ' may be a single or a number of separate areas of land. Some of the classifications recently used in vegetational or in land use surveys may offer useful beginnings, but regions must be as fully defined as local records and experience allow. To meet the requirements of policy making, very full knowledge must ultimately be available. For instance, rainfall has to be described not only by means of annual and monthly fall but by the fluctuation in these and in time of onset of the rains. Topographic detail, drinking water for man and beast, and fuel supplies are examples of the many other features which must be used with the physical primaries.

In characterizing a region controllable factors also come under careful study. Areas in which drainage or irrigation or some basic soil rectification are desirable and practicable are familiar instances.

In a great many countries, including British colonial territories, the knowledge on which to found reasoned agricultural policy is very limited. Regional differentiation will therefore be broad, and policy only in outline. Both will develop continuously as knowledge accrues from surveys, records, field trials and agricultural experience.

The next step is to decide on the suitability of each region for various crops and classes of livestock and for grass (more broadly, grazing). In addition to what past and present-day agriculture shows, possibilities may be revealed by geographic homologues. These may be sought all across the appropriate latitude belts on either side of the equator. Effectively close homologues are seldom easy to come across, but intensive search for them is, at the least, rewarded by stimulation of thought. Possibilities for new agricultural commodities or extension or improvement for some of the existing are the objective of this part of policy development. It is here that the imperative need of close association between agriculture, veterinary science and forestry is most plainly apparent.

Economic, sociological, nutritional and other aspects, though requiring expert handling, must naturally bear at all points on the primary agricultural study.

To recapitulate, the aim under this first of the three headings of policy consideration is to describe the natural resources of agriculture and to form reasoned conclusions as to the physical possibilities of production they offer. Physical possibilities may not, for the time being, be economic.

SOIL AND WATER CONSERVATION

Soil and water conservation has become established in colonial territorial policies. It is recognized that while some engineering and field works and the debarring of some areas from agricultural use are usually necessary, self-protective husbandry is indispensable. Extreme caution is better than neglect but a tendency has sometimes appeared of making conservation an end in itself instead of an element in policy.

Soil fertility, indefinable and on any interpretation not separable from soil and water conservation, is implicitly a matter for attention in agricultural policy.

FARMING SYSTEMS

Two categories of principles have been set out in connection with environment and with conservation and they have now to be linked by a third, concerned with farming systems. These are specially liable to neglect or misunderstanding where agricultural policy is drawn up without technical advice.

It is usually possible, in any region, to produce a commodity, or a selection, by alternative procedures or farming systems. All farming systems consist of one or more of four elements: crops, livestock, grass and resting land. All four may be of many kinds: grass includes clear plains, open savannah, permanent meadows and temporary leys; resting land may range from a short cleaning fallow to a long 'rest' under bush. Farming systems, correspondingly, are at one extreme livestock-owning nomadism or one crop production (*e.g.* tea, sugar) and at the other fully developed mixed farming with crops (in regulation rotation), livestock and grass worked in one system on every holding.

The principles now required are conclusions or guiding rules as to farming systems by which the resources for agricultural production could be most effectively used, subject always to their proper conservation. Every colonial territory is confronted in one or more regions with the intriguing, intensely difficult issue, between improved use of the prevalent system or introduction of a new. This appears in various forms, its essence being whether shifting cultivation, in the varying degrees in which it survives, can be displaced by some more continuous system. Displacement, on the view now prevailing, would imply a new form built from the existing rather than substitution of a complete novelty. Whether adaptations of the mixed farming of temperate climates would enable efficient, continuing production in colonial territories, can be decided only by investigation and practical trial. Something simpler may be more successful, for instance a crop rotation including green manures. Territorial policy worked out in terms of commodities and soil-water

conservation and leaving farming systems to establish themselves is risky. Some of the schemes for mechanizing peasant agriculture or for breaking in new land for agriculture seem to have accepted the risks.

CONNECTED MATTERS

In applying policy, action must be taken in a number of matters not covered by the principles or guiding rules which have been dealt with. To let these bias the study of policy would be stultifying, but it would be unpractical not to follow up the administrative, financial and other implications as each policy conclusion is being evolved. Important examples of these other matters are capital cost, availability of materials, administrative practicability, or suitable kinds of inducement (if needed) to the cultivator. Transport, nearness of markets and other facilities, may be decisive for the possibility or the form of agricultural development in an area. In some opinions the most important matter connected with agricultural policy is the outlook and technical knowledge of the cultivator. Policy must neither completely outrun present aptitudes nor be hamstrung by supposing they can never be improved.

STATEMENTS OF POLICY

Assuming principles (or conclusions or guiding rules) to have been evolved from agricultural study and examined in relation to those resulting from nutritional and other branches of study, what purposes are served ?

The importance of agriculture in all the territories makes continuing attention to food and other productions, both for subsistence and for sale, a primary task of government. This cannot be carried out either by exclusive attention to purely agricultural matters or without sound principles derived from agricultural science and experience. The policy and work of virtually every department bear on agriculture so that lively understanding among departments requires a reasoned agricultural policy in the acceptation here adopted.

For technical departments directly concerned with the land, principles for policy, evolving with growth of knowledge and experience, are the prime force in general agricultural development, in specialized research, survey and field investigation, and in all forms of advisory work.

Every field and research officer, however junior, needs the opportunity and the stimulus to appraise the work entrusted to him as a contribution to the agricultural betterment of the territory. To meet this need is one of the purposes of a policy statement. Short period production plans alone, save in periods of emergency, fail to bring out enthusiastic and informed effort.

Of the scope and form of a statement of policy evolved in the way here discussed, no one outside of the territory concerned would presume to judge. To make public a full statement would obviously be impolitic in any country, or even to circulate it departmentally. What is essential is a setting out of principles, *i.e.* reasoned conclusions, for the guidance of development and current work by specialist and general officers. This, or part of it, would be a valuable preface to the Annual Report and the Programme of Research. It would normally remain without substantial change for a run of several years. To look on it, or so to frame it that it could be looked on, as canonical

and binding, would be inimical to the evolution of policy in terms of principles derived from investigation and experience.

To give effect to the policy constituted by these principles, annual plans for action are necessary. They must deal with short-term production and also with continuing development. It is probably advantageous for a department to set these plans out, year by year, under the same headings. This helps to ensure that all concerned give thought, periodically, to all major issues.

In making and implementing agricultural policy co-ordination within and between departments is indispensable. It is, however, only an agency which must not be mistaken for a primary aim. The second quarter of the twentieth century may stand out in history as a period of excessive addiction to co-ordination, committees and conferences. An old proverb speaks of procrastination as the thief of time. There are other thieves too. Creative policy must begin in studied thought of individual minds well stocked with knowledge.

(*Received September 1953*)

Termites and Tropical Agriculture

W. V. Harris

Commonwealth Institute of Entomology

Before attempting to illustrate some of the many facets which may be observed in the relationship of termites to agriculture in the tropics, it would be well to emphasize the differences in structure and behaviour which exist among termites. It will come as less of a surprise to find that termites may have a beneficial aspect, if one is aware that not only are there many different species, but that these may differ in such fundamental matters as the absence of either the soldier or the worker caste, or in the way that they digest their food. In the very long time that has elapsed since the first termites evolved from a primitive cockroach with social habits, they have developed along a number of different lines, not without the additional complication of arriving at superficial similarities in several of the more distant branches. As a result of this it is not easy to generalize about termites, to arrange them in tidy pigeon-holes according to form or habit.

In each of the major tropical regions—Africa, America, Asia and Australia—different groups of termites have achieved dominance in their own spheres, doing things in one region which are quite different from those done by close relatives in another. For example, in Africa and Asia the very large mounds are the work of two closely related genera of fungus-growing termites *Macrotermes* and *Odontotermes* not represented in the other continents, but in Australia large mounds are built by *Amitermes*, a genus which does not produce more than a hillock elsewhere. In America there are no really large mounds, but in the Matto Grosso of Brazil narrow cylindrical mounds up to two metres high are constructed by the genus *Anoplotermes*, which is also common in Africa, but in that continent never shows above ground. Again, there is a widely distributed subfamily with nasute soldiers—that is to say their heads are pear-shaped, being drawn out into a ' nose ' through which they squirt a sticky fluid over their enemies. Some species of nasutes make their nests of dark brown carton material derived from chewed and digested wood which they attach to the trunks or branches of trees. These nests are often called ' nigger heads '. In Asia and in Mauritius foraging workers from these tree nests cause serious damage to the woodwork of buildings. In tropical America they behave similarly, but to a less serious extent, and in Africa where nasute termites more usually build small mounds on the ground, they show no interest whatever in timber, but feed on grass and vegetable debris.

Termites can be divided into two groups: the dry-wood termites that live entirely within the wood on which they feed and which they are only able to digest with the assistance of large numbers of protozoa in their gut; and the subterranean termites which possess well defined nests and go off in search of food. From the point of view of number of species, the dry-wood termites are a very small group compared with the subterranean termites.

The subterranean termites can be subdivided further into (*a*) damp-wood termites which depend on intestinal protozoa for digesting cellulose, but nest as a rule in tree-roots and old stumps at or below ground level; (*b*) fungus-growing termites, so called because their nests contain chambers filled with comb-like masses of wood pulp carpeted with fungus mycelium and serving as nurseries for the young as well as a source of food; and (*c*) a mixed residue of termites which do not grow fungi but construct nests of a cellular nature either of clay or of carton, and whose digestion of wood, plant residues or vegetable matter in soil appears to be aided by bacteria. Thus in tabular form we have four major groups:

(1) Dry-wood Termites
(2) Subterranean Termites:
  (*a*) damp-wood termites,
  (*b*) fungus-growing termites,
  (*c*) non fungus-growing termites.

Termites do not exist as solitary insects; all are social and must live in organized communities. Male and female reproductives form the basis of each colony, usually one of each sex but sometimes several females are present owing to the original queen having to be replaced by less efficient substitutes, or by the merging of two or more communities in the initial stages of development. The bulk of the colony is made up of workers, soldiers and the young stages of these and of the reproductive caste. Exceptions to this are to be noted in the dry-wood termites which have no worker caste but use the young soldiers and reproductives to do the work, and in the peculiar genus *Anoplotermes*, a subterranean termite which has no soldiers.

The food of termites is cellulose. Different species prefer to obtain it in different ways. With the passage of time the digestive tracts of the various groups have become modified to serve such preferences, as, for example, the dry-wood termites which bore in sound hard timber, the damp-wood termites which seek out timber already infected by bacteria or fungi, and on the other extreme, those subterranean termites which ingest large quantities of soil in order to extract the decaying vegetable matter it contains. Some termites harvest grass, and appear to have no other source of food. Fungus-growers tend to be more omnivorous, and some, like *Macrotermes*, will eat dead wood, fallen leaves, wooden buildings, books, and cotton clothing, as available. There are few localities in the tropics where there are not at least two different types of termites available to cope with what cellulose there may be. The branches of mangrove trees growing in tidal reaches harbour dry-wood termites, while harvester termites collect the ephemeral vegetation and the camel droppings in sandy deserts; but as soon as the mud-flats dry a little or the sands support small bushes, then more species of termites appear. The farmer in the tropics, unless living at an altitude sufficient to produce a temperate climate, has to compete with termites for the timberwork of his home and farm buildings as well as for his fences and such parts of his implements as may be made of wood, and upon all of which his success depends. While growing crops may not often be damaged, they become liable to be eaten by termites as soon as they ripen. On the

other hand, it is a matter for speculation as to what a farm would be like without the scavenging activities of the subterranean termites, and the part that they play in the breaking down of plant residues, returning the component parts to the soil. Soil fertility depends on the life which goes on beneath the surface, and in many parts of the tropics the termite appears to be an important part of this life, and therefore of some potential significance to soil fertility generally.

TERMITES AND FARM BUILDINGS

The broad division of termites into dry-wood and subterranean forms is of fundamental practical importance in considering damage to buildings. Subterranean termites can be excluded by the use of foundations designed to act as a barrier to movement up from the ground, using ' ant-proof courses ' of concrete free from cracks, metal termite shields and similar devices. Dry-wood termites cannot be excluded in this way for they enter a building on their marriage flight, and start their colonies in rafters, ceilings or furniture, wherever the young pairs can find the shelter of a suitable crack or joint. Unless a naturally resistant timber is used, all the woodwork for houses in areas where dry-wood termites occur should be made unpalatable by chemical treatment. Both the chemical treatment of timber and the construction of termite-proof foundations add to building costs, and are especially unwelcome when stores and out-buildings generally are being planned, but the choice seems to lie between this expense and the premature loss of these structures. Dry-wood termites which infest buildings are particularly important in Central America and the West Indies. Unhappily, the common West Indian dry-wood termite, *Cryptotermes brevis*, is being introduced into many other parts of the world hitherto free from this type of infestation. It has obtained a firm foothold in many places on the coast of Africa from Senegal round to Durban, as well as on the islands of St. Helena and Ascension. Few places in the tropics are without subterranean termites which will attack the woodwork of buildings, so termite-proof foundations are a necessity. If dry-wood termites are absent, it is not essential that woodwork used above termite-proof foundations should be naturally resistant or made so by chemical treatment. It is, however, a desirable precaution against defects in the foundations to use termite-proofed timber in these circumstances if costs permit.

The routine proofing of all timber used on farms would save a deal of time, irritation and actual financial loss, because the cost of timber and the wages of carpenters have risen so steeply that woodwork in any form is costly. Houses for labour, byres and cattle pens, gates and fencing, chicken coops, even the stakes for supporting garden crops are all worth the extra cost of preserving for a few more years. In the case of the peasant farmer it is most essential that his house and equipment shall not be allowed to succumb rapidly to termite attack otherwise progress will be impossible, since he will reap no benefit from the extra outlay involved in improved houses, shelter for his stock and fencing for his paddocks. Where shifting cultivation is practised, the peasant has few material possessions to guard, and when he moves on to a new settlement it is as well that the termite can remove his

derelict hut from the scene and allow the bush to take over the site. Progress beyond this stage depends on the farmer being taught to preserve his possessions, and among other things protect them from termites.

There are a number of chemicals which are of value in rendering timber more or less immune to termite attack. Some, like pentachlorophenol, are also useful for making the soil of building sites poisonous to termites for a number of years and so making an additional precaution against attack. The efficiency of these chemicals depends to some extent on whether or not the treated timber is subsequently exposed to sun and rain, or to soil moisture. They are applied as solutions, usually in the cheapest grade of mineral oil that will suit the conditions under which the timber will be used, the expensive white oils being reserved for timber for cabinet work that will require to be stained and polished, while crude fuel oils suffice for fencing posts and for soil treatment. Since the whole purpose of treatment is to provide the woodwork with a resistant skin, it follows that within reason the deeper the penetration the better. Termite repellants which are applied to timber by brushing or spraying are not, on the whole, to be recommended. It requires some form of heat, pressure or vacuum to ensure an adequate penetration, and the machinery for doing this is best installed at a sawmill or similar centre. Brushing or soaking is essential, however, for repairing the protective layer when this is broken by cuts or joints in the timber. A gap in the protection which is no larger than the head of a worker termite is enough to lead to the eventual destruction of the whole structure—a point not always appreciated by the farm carpenter.

TERMITES AND CROPS

The amount of damage that termites do to growing crops is so small in relation to the opportunity which their ubiquity would appear to offer, that there is a prevalent idea that they are never true crop pests. From this it is but a short step to the assumption that any damage done by termites to crops is of a secondary nature. There are enough records to suggest that some termites attack crops in particular localities with sufficient regularity for them to be regarded as primary pests however much they may lack the spectacular appeal of the armyworm or the cotton stainer.

Cotton is attacked by a variety of termites. In Africa, seedling cotton is damaged by the harvester termite, *Hodotermes mossambicus*, in north-west Tanganyika and the lower Shiré river area of Nyasaland. Young cotton in the Gezira irrigation area of the Sudan has its roots attacked by *Microtermes thoracalis*, a small subterranean fungus-growing species. In north-west Tanganyika sporadic outbreaks of damage by another small subterranean termite, *Ancistrotermes latinotus*, occur, and closely related species of the same genus have been reported from Uganda and Nyasaland, all attacking the roots of the cotton plant. Many cotton-growing areas in Africa have reported a certain amount of damage to more mature plants by *Microtermes*, *Amitermes* and *Microcerotermes*, which penetrate the main stems and tunnel up the centre, causing the plant to wilt. That such damage is usually reported from experimental stations does not mean that it does not occur in other places, but only that the amount of damage is not at any one time calamitous. In Pakistan the problem of termite damage was solved by

changing the variety of cotton grown in affected areas from Egyptian to American long staple.

Delays in harvesting groundnuts, sunflower and maize, arising from the demands of mechanized agriculture that a single operation should suffice when local conditions had resulted in irregular ripening, gave ample opportunity to subterranean termites in Tanganyika. Losses in yield were estimated to be as much as 66 per cent in certain sunflower fields when termites felled plants that were still green, as well as those which had reached a more obvious stage of maturity. Groundnut pods were liable to be damaged once they were ripe, and this emphasized the necessity for obtaining even maturity when harvesting is to be carried out by machines instead of by hand.

In Australia, north of the Tropic of Capricorn, the most primitive of living termites, *Mastotermes darwiniensis*, attacks with great thoroughness vines, pineapples, pawpaws, a variety of fruit trees in gardens, sugar-cane in plantations, and woodwork of all kinds. This is not surprising, however, in a termite which habitually penetrates the lead sheathing of underground electric cables in what seems to be a spirit of sheer curiosity.

Coconuts in Madagascar support the black carton nests of *Nasutitermes canaliculatus* and become so weakened by the worker termites incessantly seeking out dead and dying tissue on which to feed that the palms fall a ready prey to borers and other fatal pests.

The natural habitat of the dry-wood termites is the dry dead branches of trees. The genus *Neotermes* has developed a taste for newer wood, thus becoming a pest. *Neotermes tectonae* attacks teak trees in Java, *N. gestroi* attacks cacao in West Africa, and several species are pests of tea in Ceylon. Similarly some damp-wood termites have left rotting material for living wood and *Coptotermes curvignathus* damages *Hevea* and kapok in Java, *C. truncatus* damages *Eucalyptus citriodora* in the Seychelles, and *C. acinaciformis* feeds on citrus and grape vines in Queensland.

Pastures may have their grass removed by certain kinds of termites, especially in the drier parts of the tropics. Not only does this deprive the farmer of food for his stock, but such is the completeness with which the insects work that the ground is bared to erosion by wind or thunder-storms. True Harvester Termites of the genera *Hodotermes* and *Anacanthotermes* occur in the dry semi-desert regions of Africa and Asia, elsewhere the small mound-building genera *Amitermes* and *Nasutitermes* have earned the name of harvesters from their activities in grasslands under somewhat damper conditions.

Turning now from plants which are attacked while growing normally, there is the more prevalent problem of termite damage to plants which are temporarily embarrassed by drought or by some slight injury arising from careless hoeing, bad pruning methods, or high winds. The Englishman's traditional efforts to grow roses wherever he makes his home, the Arab's garden in a coastal coconut plantation with a few *Coffea arabica* bushes around the well, and the German planter's collection of conifers—can it always be said that they were eaten by termites only because they were already moribund and would not have survived another dry season ? Similarly the replanting of clove plantations in Zanzibar is hindered by the loss of seedlings

and saplings due to ring-barking by *Macrotermes bellicosus* and *Odontotermes amanicus* during the first year; while in Tanganyika similar difficulties are met in establishing kapok, especially if great care is not taken to get each tap-root straight in the process. High winds which cause plants to chafe at soil level lead to wounds through which subterranean termites penetrate to the pithy centres of the stems. In parts of East Africa, cotton and maize are both liable to this type of damage. Careless pruning of shade trees and windbreaks leaves dead branch-ends and large wounds that do not callous over in reasonable time, and so permit the entry of dry-wood and damp-wood termites which not only aggravate the condition but prevent the tree healing itself, thus allowing destructive fungi to gain a foothold.

More indirectly, termites are harmful to growing crops by depriving them of mulches and vegetable residues before they are broken down far enough to be available as plant food. There are many areas where mulching would be of great value to crops during the dry season, but the practice is not followed simply because termites eat up the mulch almost as fast as it is spread over the surface of the soil. It appears that termite activity is greatest in those soils which would benefit most from liberal additions of plant material, both as manure and as mulch, and this may be one reason for the necessity for such large quantities of pen manure and compost being required to produce significant increases in yield and improvement in soil texture.

It has been the writer's experience with gardens of limited extent in East Africa that the risk of termite damage to growing crops can be reduced to a very low level if the humus content of the soil can be brought to a high level and maintained there. The actual operative factor may be the enhanced moisture retaining power of the soil rather than any side-tracking of the termites to an alternative food supply, because the common destructive termites are only interested in fresh cellulose and not in well-decayed vegetable matter as provided by pit-made compost. The question of soil improvement on a field scale is outside the scope of this article. Cultural methods which will speed up the rooting of cuttings and the establishment of young trees are worth exploring in order to reduce losses in the establishment of perennial crops. Soil fumigant chemicals, such as benzene hexachloride, have proved their value, but cost of treatment is an important factor. Otherwise there appears to be little that can be done, for damage to field crops is of too sporadic a nature for precautionary measures to be economic. When damage is sufficiently regular to warrant the matter being studied, the first thing to be established is the identity of the termite concerned.

TERMITES AND SOIL FERTILITY

There is not an abundance of ascertained fact regarding the influence of termites on soil fertility. Termite mounds are sufficiently conspicuous over large areas of the tropics to have received some attention, but it is essential to establish the type of termite that has constructed the mound before comparison can be made with results from other areas or general conclusions drawn. Reference has already been made to tall mounds in Northern Australia made by a species of *Amitermes*, a genus which in Africa makes only small mounds rarely more than one or two feet high. These mounds are solid masses of soil with comparatively few chambers and galleries, hard

and dense in texture because they are built entirely of surface soil from which the organic matter has been removed during its passage through the worker termites' digestive system. In Africa and south-east Asia, mounds as large as this are the work of fungus-growing termites of the genus *Macrotermes*, and they are constructed entirely of sub-soil which is collected and used without being digested by the workers. Saliva is added by the termites to make the clay fraction into a mortar to bind the particles of sand which have been brought from below and placed in position individually. Such mounds are thus nothing more than heaps of sub-soil, which, if left to weather and erode away quietly, would usefully add minerals to a depleted top-soil, but which, if disintegrated by force and spread over the surrounding land would, more likely than not, reduce the general level of fertility. Some of these *Macrotermes* mounds have been found to contain lime in quantity far greater than occurs in the surrounding soil, even to producing a layer of nodular limestone just below ground level. Recent work carried out in East Africa by P. R. Hesse suggests that this accumulation of lime comes about only in abandoned mounds in areas of impeded drainage by purely physical processes and not from direct termite activity. Plans to make use of large mounds for adding lime to agricultural land should be based on this fact.

Small mounds up to three or four feet high should be examined before they are broken up and incorporated in the soil. If they are *Macrotermes* mounds at an early stage in growth, or made by a related fungus-growing termite they will consist of unweathered sub-soil. If their interior is a honeycomb structure of earth, this will be top-soil freed from vegetable matter by digestion and is good for resurfacing earth roads. Alternatively the central part may be constructed from the residues of digested woody material, a mass of lignin and cellulose.

There are many more species of termites which are subterranean in habit than there are mound builders, though they usually go unnoticed. Like the mound-builders, they belong to three groups, fungus growers, cellular earth nest makers and carton nest makers, differing only in being less compact in designing their nests than the mound builders. Their numbers vary greatly with the terrain, but they appear to be absent only from swamps and from altitudes with minimum temperatures too low for them. In the sandy deserts of Africa and Asia two genera, *Anacanthotermes* and *Psammotermes*, are found under conditions of low humidity and humus-free soil that would appear to be impossible for termites. It is in dry semi-desert country that termites appear to be particularly numerous, or at least to form a high proportion of the animal life present. Their galleries penetrate the soil in all directions, and these, together with the larger openings which are made on the surface to allow the winged termites to fly away from the nest when rain falls, are of importance in providing a means for the rain to sink into the soil and not be wasted as run-off. Aeration is facilitated by termite workings in the soil. These benefits are provided not only in the semi-desert areas but also in the widespread red soils of lateritic origin which pack hard and tend to have sun-baked crusts which are impermeable to intermittent rain showers. In dry areas termites are driven deep into the earth during the hot season in order to keep their nests moist and cool. They come nearer the surface during the rains, and this up and down movement increases their effect on the soil.

It is a moot point just how far termites are of value in carrying organic matter down into the soil and permitting its incorporation. The efficiency with which they extract the maximum value from food material brought into the nest suggests that they contribute little to soil fertility in this way. In the nest nothing is wasted, not even corpses, and in laboratory studies of termite nutrition in worker termites, dead bodies have proved to be a valuable addition to the diet of the survivors. The only appearance of food wastage, and this is insignificant in amount, is when, during the rainy season the fungus-growing colonies spread a part of the comb material on the surface of the ground to produce a crop of mushrooms which appears to have no interest for the termites.

SUMMARY

The varied nature of termite behaviour is stressed in view of the dangers of applying to one area the conclusions derived from their study in another area, without full consideration. Four main groups of termites are suggested, based on their habits of nest construction and correlated feeding habits. Consideration of the relations between termites and agriculture in the tropics is under three heads—destruction of buildings, damage to crops and influence on soil fertility.

(*Received September 1953*)

REFERENCES

MacGregor, W. D. (1950). 'Termites, Soil and Vegetation.' *For. Abstr.*, **12,** 1

Griffin, F. J. (1951). A Bibliography of the Isoptera (Termites). *J. Soc. Bibl. nat. Hist.*, **2,** 261–368

Ratcliffe, Gay and Greaves (1952). 'Australian Termites.' Melbourne, *C.S.I.R.O.*

Hesse, P. R. (1953). 'Study of the Soils of Termite Mounds.' *Rep. E. Afr. Agric. Res. Org.*, 1952

Spraying of Cattle as a Method of Control of Cattle Ticks and its Field Application in Ankole District of Uganda

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A tick problem exists in Uganda but the degree of infestation is extremely variable. Ankole District in the south-west of the Protectorate is an excellent example of an area of extensive grazing and heavy tick infestation.

The species of Ixodae which are of greatest importance in Uganda are the brown tick (*Rhipicephalus appendiculatus*), the Bont tick (*Amblyomma variegatum*) and the red tick (*Rhipicephalus evertsi*) (Wilson, 1950). The effects of infestation of these ticks on livestock are many, but always adverse.

Rhipicephalus spp. transmit East Coast Fever, a blood disease (*Theileria parva*) which causes heavy mortality in poorly nourished calves. Tick infestation is a contributory cause of anaemia and stunting in growing stock, and stunted calves are common in a heavily tick-infested area.

Tick bites damage the skin, especially of the udder and ears, leading to bacterial invasion. Ticks are also responsible for loss of condition in adult stock, due to loss of blood and to irritation.

Rhipicephalus spp. can be found in certain areas to infest cattle at a level of 300 nymphs and adults per ear with total counts over 1,000 per animal not uncommon. The late effect of heavy infestation with nymphs and adults of *R. appendiculatus* and larvae and nymphs of *R. evertsi* in the ears is frequently a bacterial otitis, leading to sloughing of the external ear. This has been shown to be due to infection with *C. pyogenes* (Taylor, 1953). Similarly the deep bites of *Amblyomma spp.* on the udder cause great reaction in the skin and lead frequently to mastitis.

The control of such adverse effects is obviously of great importance to an area in which cattle are the principal wealth and source of food.

The cattle of Ankole District are the Ankole longhorn; on the eastern edges of the district an admixture with Zebu cattle takes place and crosses between the two (Nganda) occur. Exotic breeds are not present.

Of the 200,000 head of cattle in Ankole District it is estimated that one quarter, or some 50,000 head, exist in areas where *Rhipicephalus* infestation is serious, while one half, or 100,000 head, exist in areas where a medium infestation occurs, but where the position could deteriorate to become bad. The remaining quarter is in general kept on semi-nomadic lines in an area of low cattle population where regular and widespread grass-burning occurs each year, though these conditions are not necessarily the only ones responsible for the low tick population. These cattle have relatively few ticks, often less than ten nymphs and adults per ear, though observation of

the external appearance of the lymph glands of the calves leads one to believe that the infection rate of East Coast Fever is just as high (near 100 per cent) as it is in the more heavily tick-infested herds. All these cattle are owned by Africans, most of whom hold extremely conservative views, especially in respect of their cattle.

Clearly, in order to increase the productivity of the indigenous stock it is essential to reduce the effect of the large-scale tick infestation. It might be thought that the most logical way of doing this would be to introduce compulsory weekly dipping with a view to tick eradication and control of East Coast Fever. Administrative and technical difficulties, however, make such schemes impracticable.

Work at experiment stations in Uganda has shown that most well nourished calves of both Zebu and Ankole breeds survive their usual attack of East Coast Fever. Under field conditions this is inevitable during the first three months of life. Following this attack they have a strong immunity against this disease. In an area where tick eradication has been successful calves do not contract East Coast Fever. However, if at any time, through movement or sale, these animals become suddenly exposed to transmission of East Coast Fever, they immediately succumb to a severe attack of the disease which is very likely to prove fatal.

Complete eradication of tick infestation is difficult and undesirable, and there is no reason for initiating dipping schemes for tick eradication such as are necessary in Kenya and Tanganyika in and near areas containing highly susceptible European cattle.

At the same time, the cost of transport of the materials and the erection of permanent dips is initially exceedingly high (£800) and is further complicated by the need for an abundant water supply, means of safely emptying the dip, the ability to test the strength of the dip frequently and to measure the necessary replenishments. Even if these factors are readily met it is clear that wide areas must be rigidly included in such a scheme, and movement of cattle into the area closely and efficiently checked. This control would require large-scale staffing and supervision with little significant benefit.

To control ticks entirely, then, is undesirable unless a uniform eradication of ticks over a large area is possible. At the same time owing to the adverse effect of heavy tick infestation it is very desirable to limit their effects while not reducing the tick infestation to the level when infection with East Coast Fever does not occur. This effect can be obtained most easily and economically when judged by cost, portability and general efficiency, by spraying cattle with portable spray pumps using the newer residual tickicides such as benzene hexachloride or chlorinated camphenes, of which a number of preparations are available on the market.

By the use of portable sprays the water problem is simplified and the massing of cattle in large mobs for the purpose of dipping can be avoided—a system which leads to soil erosion and facilitates the spread of disease. The technique of spraying is also more flexible and capable of modification as compared with dipping.

The sites of preference for cattle ticks are known in some detail (Wilson, 1946; 1948) and it is therefore a simple and relatively economical matter to spray cattle, paying special attention to the sites of greatest importance,

namely the head, ears, dewlap, udder and perineum. This knowledge together with the advent of suitable tickicidal preparations means that about two pints of fluid per animal is sufficient to cover the sites of attachment and have enough residual effect to keep the animal partially free from tick infestation for a number of days after spraying.

Type of Apparatus—The use of small portable spray pumps which can be purchased by an African cattle owner or by a collection of cattle owners in a co-operative movement, is an important advance in the control of heavy tick infestations. The types of pump available are many and varied, but the essential features are simplicity of design, durability, ease of repair and replacement and the capacity to raise a minimum pressure of 50 lb./in.^{2}. In general the small pumps intended for single-handed operation are laborious when more than a few cattle are to be sprayed; and the most satisfactory and widely used pumps have been those designed for operation by two persons. It is an advantage if two hoses and lances can be fitted, and in this way cattle can be sprayed from both sides of a crush at the same time and the rate of treatment is greatly facilitated.

After extended trials the pneumatic type of sprayer was discarded as it was laborious to work and a constant pressure was difficult to maintain. Several types of bucket or stirrup pumps were tested and the most satisfactory of these initially tested both from simplicity of design and durability was the 'Nesthill' Universal Pump distributed by Cooper, McDougall and Robertson (East Africa), Ltd. Fitted with suitable jets, this pump could deliver one gallon of spray per minute at a pressure of around 80 lb./in.^{2}; fitted with two 30 ft. hoses, up to 80 lb. pressure, with a delivery of about three-quarters of a gallon per minute, can be attained. The pump is fitted with an all-metal piston to which suitable gland packing can easily be re-applied to compensate for loss of pressure through continuous wear. The current equivalent pumps supplied by Cooper, McDougall and Robertson are the Columbia (single hose about 125s.), the C.S.1. (single hose about 140s.) and the C.S.2. (double hose about 225s.). The Eclipse Leader Junior Pump (Eclipse Spraying Co., Smethwick) has the advantage that the pump is not immersed in the spraying fluid and it is stronger and more robust but somewhat more expensive, and having rubber washers requires more attention. An Eclipse Leader Senior Pump with double lead is similar in use and can deal with about 75–100 cattle per hour.

The size of spraying lance attached to the delivery hose should be at least 18 in. and not more than 24 in. long, with the centre of balance near the grip, for if the weight is too far forward the lance is tiresome to work. The delivery can most easily be controlled by a trigger release. The most important part of the lance is the delivery nozzle as the effects of the best pump can be spoiled by fitting unsuitable nozzles. The 'Nesthill' pump was originally fitted with a hand T-piece carrying four jets. This was found to have certain disadvantages in that the fine jets tended to become blocked, and the delivery, being rather profuse, was somewhat wasteful. The double nozzle 'Bordeaux' pattern was preferred as the angle of the nozzles to the spraying lance is capable of adjustment.

The newer nozzle fitted to the Columbia, C.S.1. and C.S.2. depends on a replaceable plate fitted inside the cap. It is detachable and easily cleaned

Figure 1. An Evans hand ram in action showing the method of passing a second hose to the far side of the crush

Figure 2. The double nozzle 'Bordeaux' pattern showing the angle of the nozzle to the lance

but can be easily lost under field working conditions. In other types the swirl plate is a continuation of the lance and is fitted with a central pricker. This type is also easily cleaned.

The type of nozzle with swirl plate screwed into the cap behind the movable disc, has the advantage that new discs with different size orifices can be fitted easily.

It is of considerable advantage if these nozzles can be fitted to lances with angle bends as the spray can then be directed upwards to reach the undersides of the body. The most suitable size for the orifice in the nozzle disc was either 1/16 in. or 5/64 in. in diameter. Sturdy construction of the hand spray lances mitigates many delays in the field.

Tickicides—Early experiments were carried out with a proprietary dispersible powder which contained 50 per cent B.H.C. and 6·5 per cent of the active *gamma* isomer. Since one pound of this powder contains 0·065 lb. of *gamma* isomer, 1½ lb. powder diluted in 100 gal. of water contains 98 parts of *gamma* per million, and at this strength, using two pints of fluid to spray the sites of tick attachment, over 80 per cent of *R. appendiculatus* and *A. variegatum* ticks attached on the day of spraying, were dead 24 hours later. The cost was a little in excess of one cent per head per spraying, or in the region of 60 cents per head per annum.

The results with powder stock dip were very similar to those obtained with dispersible powder, and owing to the ease of dilution and tick-killing properties, this was a very suitable preparation for spraying.

Two difficulties arose in the use of *Gamatox 2*. This paste dip contains 50 per cent B.H.C. and at least 10 per cent active *gamma*, so to give a preparation containing 100 parts of *gamma* per million, 20 lb. of the paste (which is equivalent to 10 lb. B.H.C. and 1 lb. active *gamma* isomer) must be mixed with 1,000 gal. of water. To prepare small quantities it is not sufficient to take a proportion of the paste from a tin of *Gamatox 2*, as there is no assurance, after long storage, that the B.H.C. content is evenly distributed in all parts of the paste at the time of mixing. In any case a tin once opened must be used as soon as possible as it hardens after some weeks. It is therefore advisable to prepare a stock solution, say a 10 lb. tin of *Gamatox 2* thoroughly mixed in 25 gal., and at the time of spraying one gallon of this stock solution is mixed with 20 gal. of water to give the correct strength of 100 parts *gamma* per million. At the retail price of Shs. 50 per tin the cost of 10 gal. of diluted spray, sufficient to spray 40 animals, is 100 cents or 2·5 cents per animal, or Shs. 1/30 per animal per annum.

These difficulties of mixing were overcome by using the Gamatox Liquid Cattle Dip and Livestock Spray, containing 25 per cent B.H.C. and 2·5 per cent active *gamma*. One gallon of this dip at the retail price of Shs. 23/50 per gallon, diluted in 250 gal. of water, gives a solution containing 100 parts of *gamma* per million. This quantity is sufficient to spray 1,000 head of cattle at a cost of 2·35 cents per animal or Shs. 1/20 per animal per annum.

Later comparisons have been made between *Gamatox 3* and preparations containing chlorinated camphenes (*Coopertox*) (Taylor and McAnulty, 1951). These authors concluded that benzene hexachloride spraying does not give adequate protection for more than six days after spraying and that, ideally, cattle should be sprayed on the sixth day. The residual effect of the

chlorinated camphenes lasts longer and at a dilution of 1 : 150 protects for up to 10 days. More recent experiments using *Bexem* which contains 17 per cent benzene hexachloride and 4 per cent *gamma* isomer at a dilution of 1 : 200 have shown a tick kill of 95 to 92 per cent on the first three days after spraying and the kill was still above 60 per cent up to the seventh day when it fell to 50 per cent.

FIELD APPLICATION IN ANKOLE

In 1949 a demonstration spraying centre was started in Ankole District in an area chosen for the co-operative attitude of the people. The cattle population was approximately 1,000 head. A crush for handling the cattle and a hand pump were installed, paid for by Protectorate Government funds. *Gamatox 2* tickicide was supplied and used at a dilution of 1 : 200 and after careful attention to the general disease situation in the area spraying was begun in November, 1949, under the supervision of a selected number of Departmental African staff residing in the area.

Once control of cattle movement as a measure of disease prevention was accepted, the responsibility for allowing cattle into and out of the area was handed to a committee formed of popular cattle owners. The local Chief and the Veterinary Staff were included on this committee, whose president was elected by general assent at a meeting of all owners. The area itself was given the title of Livestock Improvement Area. In support of this title the cattle were treated with dimidium bromide on two successive occasions to eradicate sporadic outbreaks of trypanosomiasis; and a regular vaccination against anthrax and blackquarter was initiated. These measures were designed to secure and maintain the interest of the cattle owners, and to remove some other factors affecting conditions and mortality. Regular inspections by the Veterinary Officer were made.

The results achieved were successful and a reasonable degree of weekly spraying was obtained. It should be remembered that tick infestation is only one factor influencing the health of these cattle, and that the choice of area was influenced by the co-operation of the owners, in addition to the tick infestation. Advice on good calf rearing, the value of bullocks and mixed farming was, from the start, constantly given by staff. The centre-piece was, however, occupied by the spraying, physically emphasized by the weekly convergence of the cattle on the crush. This important principle was accepted as a routine and criticism from outside parties concerning the imaginary harmful effects of *Gamatox* was dispelled. Such prejudice is one of the largest obstacles to real progress.

The discussions in neighbouring cattle areas must have been endless during 1950, and led, in 1951, to requests by neighbours to be granted the same facilities. It was foreseen that these demands would lead to an ever-increasing commitment. These neighbours were, therefore, encouraged to form themselves into voluntary associations. Each association maintained approximately 1,000 head of cattle and the owners subscribed a small sum of money per head and helped to build their own crush. At this stage the rudimentary scheme was much assisted by the availability of the accumulated profit from a small Ghee (clarified butter fat) Industry started by the Veterinary Department in Ankole as an emergency war-time food production measure.

This fund provided a source of money, handled by the Ankole African Local Government (who showed themselves favourable to the scheme), from which assistance could be given through the authority of the District Commissioner to meeting the cost of crush building. Thus, the onus of this cost was removed from the cattle-owner's subscription. This removal of the cost from the owners' shoulders was important.

With this background and with the agreement of the African Local Government to sell the poles from their plantations for building cattle crushes, it was possible to calculate an initial subscription of 50 cents (sixpence) per head of cattle to cover the purchase of pumps and tickicides and a year's spraying, on a weekly basis. In due course after increases in the cost of pumps and tickicides, it was found that this amount did not cover the full year, but this fact was accepted by the cattle owners.

The organization provided by this scheme answered a large demand and the popularity of spray centres was gratifying. By the end of 1952 some 40 centres were either functioning or forming, mostly situated in the badly infested areas. The formation of centres in areas of medium infestation is to be encouraged, while in lightly infested areas a conscientious stock-owner would spray the udder and perineal region of his adult stock.

Supervision of such spray centres is provided by Veterinary Department staff, the majority of which, for these purposes, fill posts paid for by the Ankole African Local Government. Fresh subscriptions are collected when necessary in each individual centre.

DISCUSSION

It must be realized from what has been said that those stock-owners who readily pay the subscription have started thinking in a 'modern' way in regard to their cattle. The sight of a Muhima tribesman bringing his herds to the crush on his appointed day in the week and with his own hands spraying his cattle represents a significant advance. This sight can now be seen in Ankole, and this fact alone is an important one. Also it is true that whether or not an owner brings his cattle regularly each week, every time he does spray the resulting tick kill is of direct benefit. Regular spraying gives the best results, as is well shown in the case of an excellent demonstration herd maintained in a bad tick area on a regular weekly spraying basis, supervised and staffed by Departmental personnel. All persuasion is given to owners to obtain regular weekly spraying at the centres and the very fact that a man has paid makes him more likely to attend.

Inasmuch as many factors can be combined to produce healthy stock, so there are factors conspiring to lower productivity. This is true of any agricultural or pastoral community. In Ankole a factor as big or bigger than those of disease, fodder shortage, ticks or bad calf management, has been the conservative practice of keeping cattle as an end in themselves and not as a means to en and. This negative aspect of herd management is of course common throughout Africa. Conversion into productivity depends upon gradual acceptance, step by step, by the African, of advice and instruction, and much of this can most conveniently be given by example.

In this article one of the factors reducing productivity in cattle is treated more or less as an isolated problem. This is necessary in order to explain

the method of extension of facilities of tick control to a large section of the cattle population. As well as bearing in mind that this is but one of many harmful factors, it must be realized that real success in introducing any new method of stock management on a voluntary basis in an African community, not imposed by legislation, can represent fundamental progress. Combination of modern practices with tribal customs of cattle management, many of which are of great value, can be done by good demonstration and the exercise of tact and restraint.

The important matters of handling African staff and the approach to cattle owners are unfortunately outside the scope of this article, but the great value of frequent visits by the European Officers concerned and the personal contacts which this achieves, cannot be over-estimated in obtaining real progress.

SUMMARY

The reasons, method of development, value and significance of a scheme of tick control by spraying, supported largely by voluntary subscription by African stock-owners is described.

ACKNOWLEDGMENTS

Thanks are due to the Director of Information, Uganda, for permission to reproduce the photographs; to the Director of Veterinary Services and Animal Industry, Uganda, for permission to publish the paper; and to D. H. L. Rollinson, Ph.D., M.R.C.V.S., for comments and criticisms.

(*Received September 1953*)

REFERENCES

TAYLOR, J. I. and MCANULTY, E. G. (1951). 'Benzene Hexachloride and Chlorinated Camphene for spraying cattle.' *E. Afr. agric. J.* **17,** 12

— (1953). Unpublished information

WILSON, S. G. (1946). 'Seasonal Occurrence of Ixodidae in cattle in Northern Province, Nyasaland.' *Parasitology,* **37,** 118

— (1948). 'A Method of assessing the acaricidal properties of D.D.T. and "Gammexane" preparation in field trials.' *Bull. ent. Res.,* **39,** 289

— (1949). 'Control of ticks by spraying.' *Rep. vet. Dep. Uganda,* p. 26

— (1951). *E. Afr. Veld.,* **1,** 5, 76

The Development of Rice Research in Sierra Leone

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The peoples of Sierra Leone, almost without exception, depend upon rice as their main food crop. It is likely that some form of rice cultivation has existed for a very long time—probably using varieties of *Oryza glaberrima*—but the more extensive cultivation of *O. sativa* varieties is usually assumed to date from the time of the earliest Portuguese colonists.

Until the latter part of the last century practically all the rice grown was upland rice. The method used was the traditional native system of bush fallows, which still persists. Owing to the increase of the population, the length of the fallow period has become shorter, and degradation of the soil has become serious in places. Taking the country as a whole, upland rice still constitutes the larger part of the total crop, but the development of swamp rice cultivation has increased steadily in recent times and is continuing to do so.

About 1880, the farmers at the mouth of the Little Scarcies river began to develop the tidal mangrove swamps. Along the Great and Little Scarcies rivers there are extensive swamps of this nature and by 1920 the area under rice cultivation was so noticeable that the prospects of further development were considered. Two members of the Indian Department of Agriculture visited Sierra Leone to investigate the possibilities and to advise on methods of cultivation. Following on their recommendations the system of swamp rice cultivation evolved by the Scarcies farmers was successfully introduced to farmers in the tidal swamps of the Southern Province. Detailed surveys of existing and potential areas of rice cultivation in tidal mangrove swamps were subsequently carried out by Agricultural Officers of the Department of Agriculture. R. R. Glanville surveyed the Scarcies area in 1930, and in 1938–39, G. M. Roddan surveyed the tidal swamps in the Southern Province, and the grassy swamps of the Bum Kittam river system.

The tidal mangrove swamps, which are very extensive on both the Great and Little Scarcies rivers, have been cleared for the most part of mangrove vegetation by the local farmers, and now form the largest concentrated area of rice cultivation in the country. They lie on both sides of the rivers, being widest at the mouth and narrowing to the point where they cease. In the rivers during the growing season, the water is completely fresh, being backed up by each high tide and flooding over the rice lands. During the dry season the flow of the rivers is greatly reduced and salt and brackish water floods the land at the spring tides. This land bears a crop of rice every year—being fallowed during the dry season. Fertility is probably maintained by silt deposition and, owing to the saline flooding in the dry season, weed growth is discouraged—the only weed of any importance

being the salt-resisting grass *Paspalum vaginatum*. Cultural practices are few, the usual native farming calendar being as follows:

March–April: Shallow hoeing to remove the *Paspalum* where this is plentiful. There is a growing tendency in recent years for this to be delayed until just before planting time.

June–July: Nurseries are sown on the upland, usually in the vicinity of towns.

August–September: The rice seedlings are transplanted to the swamps.

December–January: The crop is harvested.

Yields are, in the main, between 1,000 and 2,000 lb. of paddy per acre.

An agricultural station was opened in 1934 at Rokupr on the left bank of the Great Scarcies river, and about 20 miles from its mouth. It was intended for experimental work on rice-growing in the tidal mangrove areas, and as a source of pure seed of improved varieties for distribution to farmers. Up to the present time work at Rokupr has been mainly on the type of tidal mangroves swamps described above. Experimental work has occupied much of the time of agricultural officers stationed there, but it has had to fit in with other agricultural activities, and during the war years it was curtailed by the demands of war-time food production.

Some of the earliest experiments laid down at Rokupr were in connection with local farming practice. The native farmer in planting his farm usually places a large number of seedlings in each stand and spaces these stands widely. This practice is partly due to the contract system of planting employed by many of the larger farmers, and partly to the fear of damage by crabs. A series of experiments at Rokupr showed positive advantages in a spacing of 6 to 9 in. and the placing of two to three seedlings in each stand. This was adopted as the standard practice on the farm and given as advice to the local farmers through the extension service. It has later become apparent, however, that in areas where crabs cause extensive damage to seedlings, a higher number of seedlings to the stand may be advisable. A further series of experiments on nursery practice showed higher yields when the seed rate was low (200 lb. per acre) and when the seedlings stayed in the nursery for eight weeks before transplanting. This was on rather infertile nurseries on the upland. At a later date new nurseries were made at the edge of the swamp and experiments showed that a much higher seed rate could be used without any adverse effect on yield or survival of seedlings, and also that the nursery period could be reduced to six weeks. A seed rate of 700–900 lb. per acre is used at present in the nurseries. It was also found that these nurseries did not suffer so badly from *Piricularia* as those on higher ground.

An experiment was laid down in the years before the war on methods and time of cultivation, and this ran for a number of years. Factors investigated were shallow versus deep digging; digging annually versus digging each second and third year; and digging in February versus digging in July. Deep digging (approximately 8 in.) proved superior to shallow digging; early digging was superior to late digging; there was little difference between the plots of one series dug in any one year; there was little residual effect from the digging, and annual digging is necessary to maintain yields.

Deep digging annually in February gave the best yields and this practice was made standard on the farm. In recent years a change in the native practice of early digging to late digging of land which is covered with *Paspalum vaginatum* has become very noticeable and experiments are in progress to see whether there is any sound basis in this practice. It is clear that early digging hinders regrowth of this grass, but yields in preliminary observations have been conflicting. Farmers say that early digging holds up salt water, thus necessitating later planting.

In former years the price of the rice crop had been so low in comparison with the cost of fertilizers that their use was not considered economic and no trials were carried out. In recent years, however, the price of rice has risen to such an extent that fertilizers could be used by the farmer under certain conditions. On rich tidal land, it is doubtful whether there is any worthwhile response to fertilizer application. Towards the higher ground trials have shown very definite responses to superphosphate. There is not only a high response in the year of application but a marked residual effect. Similar results have been obtained in inland swamps.

Improvement of the swamp rice crop has proceeded on two parallel lines; the introduction and testing of new varieties of rice, and the improvement of local varieties by selection. Latterly hybridization work has been started.

With a view to a future export market, only white grained rices have been selected and the final criterion has been yield, though undesirable characters such as weak straw have been eliminated. Milling quality has not, so far, been investigated though it is hoped to do so in the near future.

Some 300 varieties of rice have been introduced from most of the rice-growing countries of the world. New introductions are multiplied and planted in observation plots in the first instance. Many of them have shown themselves unsuitable for local conditions and have been discarded; others which, while not being outstanding have shown useful characters, have been kept for future breeding work; others again have been tested in statistical yield trials against proved varieties. After several years observations and testing a number of varieties have been multiplied and distributed to farmers and some of these are now widely grown and are of great popularity. Examples of these rices now widespread are:

150 days duration, Lead, D99 and No. 79 from British Guiana
160 ,, ,, G.E.B.24 from Madras
180 ,, ,, Sughandi (A28/6) from Burma
190 ,, ,, Ngasein (C19/26) ,, ,,
200 ,, ,, Indo-China (deep water floating rice) from French Sudan
210 ,, ,, Kavunginpoothala from Madras.

Reselection has been carried out on all these and, of the last three, the selections Ngasein 57, Indo-China 53 and Kavunginpoothala 12 have proved the best.

More recent introductions which have not yet been fully tested contain some very promising varieties, notably some early rices from Tanganyika and Thailand, medium duration Burmese rices and late types from Malaya, North Borneo and Orissa.

Native rice varieties have a multiplicity of names, and samples have been collected at Rokupr over a number of years. These have been examined and a preliminary classification carried out on grain characters and a list of synonyms prepared. New native varieties received are compared with type samples and grown for comparison in the field. These varieties are on the whole very mixed, containing both white and red grained types and, apart from a little mass selection carried out by the Scarcies farmers, nothing is done to improve them by the local people. Pure line selection of native varieties was one of the first tasks undertaken in the early days of the station, and several early selections proved most popular with local farmers. At the end of the war this work was resumed and reselection of many of the introduced varieties was also set in hand. These had been grown in bulk for a number of years and had become genetically impure.

Of the original pure line selections only two, Bolo 108 and Toma 112, have retained their popularity; others have been replaced by more recent introductions and selection. At present pure lines of thirteen varieties are in various stages of trial and some of these are types for special conditions such as the deep water floating rice Indo-China for the Bonthe grasslands. Four selections of this rice have been retained as giving a considerable increase in yield over the unselected variety and, of these, No. 53 is proving more resistant to wash than others. Six selections of Pokkali from Ceylon, said to be salt-tolerant, await further trials and may be suitable for more saline areas near the coast.

Hybridization was first started in 1951. Rhind's method of emasculation by forcing flowers to open in warm saturated air in a vacuum flask was successfully adopted and a pollination technique developed. A high percentage of crossed seeds was obtained and these are now being grown in the F2 generation.

Proved new varieties are multiplied at Rokupr and pure seed distributed to other parts of the country and to the Scarcies farmers. This distribution was originally carried out through a loan scheme but at present seed is sold to the farmers and to local authorities who carry out further multiplication. While a high standard of mechanical purity has been retained in Rokupr seed, there has been a falling off in the genetic purity and reselection has been necessary in most of the older varieties. Bagging of individual plants has now been started and in future all seed distributed will be only three or four generations away from a single plant selection.

Although improved varieties put out from Rokupr are widely grown, native varieties still form a very high proportion of the crop. There is thus a full programme for several years ahead for the plant breeder. In addition, many special types are needed for land being developed for rice growing, for example, floating rices for the Bum Kittam grasslands, and varieties that will stand submergence for the flood plains of the middle reaches of the rivers in the north and west of the country. Upland rice also is capable of considerable improvement. Although the policy of the Department of Agriculture is to reduce cultivation of this crop it will always be grown as the main cereal in any upland cultivation of annual crops, and yields can almost certainly be increased by selection. Some preliminary work has already been done.

Rice in Sierra Leone is remarkably free from pests and diseases. Army worms (*Laphygma exempta*) in some years attack upland rice soon after sowing but rarely do any lasting damage, and crabs on the tidal land can destroy freshly planted seedlings, but neither are of widespread importance. *Piricularia oryzae* attacks seedlings in the nursery stage to produce symptoms of ' scorch ', but cannot be said to be a major disease. There is evidence that vigorous healthy seedlings rarely show heavy infection, and there are distinct differences in varietal susceptibility to this disease. *Ephelis pallida*, which occurs on wild grasses, has been found on rice at Rokupr, though nowhere else in the country.

Although weeds are not a serious problem on the tidal lands, on other types of rice land some grasses and sedges can be troublesome—notably the wild perennial rice *Oryza barthii*, and *Cyperus rotundus* in fresh water swamps which do not dry out, and *Ischaemum rugosum* on the drier rice land.

It is hoped that the botanist will be able to investigate some of the problems which appear to be connected with the physiology of the rice plant.

One such is the question of duration. Introduced varieties have often had markedly different life periods from those obtaining in their countries of origin—often in similar latitudes. Indications are that light intensity might be one of the factors involved, tolerance to saline and acid conditions are other characters that may be investigated better by laboratory methods in the first instance.

A small rice mill was run for a time on a commercial basis at Rokupr but was discontinued after the establishment of a full sized rice mill on the Scarcies by the Department of Commerce and Industry. Little has been done to date in respect of milling and commercial quality, but this must be taken into consideration in the future breeding programme.

There are areas outside the rivers near the coast, where the water is always saline. There the land must be bunded and rice grown as a rain-fed crop. Such areas are found in the eastern parts of the Colony Peninsula and in the Scarcies area near the French Guinea border. They are characterized by a preponderance of the mangrove *Avicennia nitida*, in contrast with the soils already mentioned, on which *Rhizophora sp.* predominate. It was decided in 1943 to bund the farm at Rokupr, and this work was carried out in the 1943–44 dry season. It was expected that, by having complete water control, yields would be increased and it might be possible to grow other crops on the land in the dry season. Yields in 1944 were in general good, but in 1945 serious adverse soil conditions developed over a large part of the farm and yields were poor. In 1946 and 1947 there was a spread of this trouble, much of the land became completely unproductive, and the rice seedlings died soon after they were planted. In the absence of a chemist it was not possible to investigate the situation thoroughly, but rough analyses showed high concentrations of ferrous iron and sulphate in the soil. A number of different cultural practices were tried out but none proved effective in ameliorating the conditions. It became increasingly obvious that while the tidal water was excluded and the soil allowed to dry out thoroughly in the dry season, this problem would remain. In the 1947–48 dry season the bunds were cut and tidal conditions restored. There was an immediate improvement in the 1948 season and by 1949 the land was back to normal.

While the immediate problem of restoring the fertility of Rokupr farm had been solved, the practical problem of empoldering *Rhizophora* areas remained. It was realized that for full investigation a soil chemist would be essential, but in the meantime an observation with four small plots had been laid down to run for ten years. Of these four plots, one remained tidal, one was completely controlled, one was controlled in the dry season and made tidal during the rains, and the fourth controlled in the rainy season and made tidal in the dry season. The completely controlled plot failed to grow any rice at all in the second year, following on a poor crop in the first year. The two partially controlled plots have given good yields throughout, if anything, slightly better than surrounding tidal land. There has been little to choose between them, with possible slight advantage in favour of that controlled in the rainy season. Two further plots were added to this observation later, these had small bunds which, while holding water on the plots, were low enough for the tide to flow over. They have had a heavy annual silt deposition and have given higher yields than all others.

While experiments have shown that empoldering of lands which bear, or have borne, *Rhizophora* mangrove is likely to lead to trouble, the empoldering of saline lands under *Avicennia* mangrove near the coast has been done successfully, since the soil problems of this type of land are different. It has recently been determined that the *Rhizophora* mangrove in Sierra Leone is not all of one species—in fact three species occur—and it is possible that adverse soil conditions will only be found on empoldered *Rhizophora racemosa* land. The other two species, *R. harrisonii* and *R. mangle*, grow in slightly different habitats and these may be capable of development by empoldering, though this has not yet been investigated fully.

An herbarium has been started, mainly of plants from rice-growing localities. Duplicates are sent to Kew and to the Departmental Herbarium at Njala.

Other work which may be briefly mentioned had been the calculation of the economics of native practices, a few small experiments on sampling methods, and the distribution of rice varieties to other countries.

With the expansion of the Station as a Regional Commodity Research Centre, the problems common to all West African Territories will be a first charge on the work of the research officers.

(*Received September 1953*)

The Teaching of Tropical Agriculture in Europe—I: The Netherlands

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Instruction in tropical agriculture in the Netherlands is built on two main principles, (1) education to the degree of M.Sc. on university basis and (2) education of practical tropical agriculturists.

The first-mentioned instruction is given at the faculty for Tropical Agriculture at the Agricultural University College, Wageningen, the second one at the State College for Tropical Agriculture, Deventer, and at a few other agricultural high schools provided with a department for tropical agriculture.

Finally, some time ago, at the Agricultural University College, Wageningen, special courses were founded with a view to tropical specialization for postgraduate foreign agriculturists. This education of foreign students, which is sponsored by the International Agricultural Study Centre, Wageningen, has been divided into university courses at Wageningen and high school education at Deventer.

THE AGRICULTURAL UNIVERSITY COLLEGE AT WAGENINGEN

The instruction at Wageningen is divided into four faculties: Agriculture in Temperate Regions, Agriculture in the Tropics, Silviculture and Horticulture.

The period at the Agricultural University starts with a propaedeutic study lasting 16 months, in which time the scientific and economical bases are established for agricultural science proper. This propaedeutic study is the same for every course of study and comprises tuition in mathematics, hydraulics, mechanics, physics, meteorology and climatology, chemistry, mineralogy, petrology and geology, botany, political economy and general agronomy. These are all fundamental subjects in which, right from the start, account is taken of what the student will have to know of the applied subjects that follow afterwards. For some of these subjects the student may not sit, unless he has also done the relevant practical work.

After the ' propaedeutic examination ' the student has to choose the course of his further study, but, no matter what course he takes, he will always need some more general knowledge not taught in propaedeutics. Thus, after propaedeutics, in a two year Bachelor's study, the tuition of all courses of study is continued in the mathematical treatment of agricultural results and in botany, plant-physiology being the chief subject dealt with. Other branches of study for the Bachelor's examination, besides those mentioned, depend on the course of study chosen by the student.

Those students who wish to proceed to studies in the faculty for Tropical Agriculture will have to make further specialization in each of the three

sub-faculties: Tropical Crops, Animal Husbandry in the Tropics, and Agricultural Economics in the Tropics. As a matter of fact these different specializations do not diverge in all subjects. Naturally, there are various subjects which should be studied both by the students who take their instruction in the faculty for the temperate as well as for the tropical regions, and, of course, this applies the more for the subjects of the sub-faculties. Hence, the type of specialization lies in the variety of the combination of compulsory subjects.

The second part of the study, in which part the student has a preliminary basis for specialization, may be finished after two years with the candidate's examination in Tropical Agriculture. The standards are more or less equivalent to B.Sc.

After the B.Sc. degree the third part of the study is tackled. Through a choice of four subjects for the final examination a further specialization is reached. For each of the sub-faculties two out of these four subjects are compulsory; the other two may be chosen by the student.

Thus a student, having chosen after his first examination the faculty for Tropical Agriculture, and in this faculty the course on Tropical Crops, is obliged to take the subjects Tropical Crop Husbandry and Agricultural Chemistry, but he is free to choose the two remaining subjects.

With these he will be able to specialize, that is, as a plant-breeder by choosing the subjects genetics and plant breeding, or he may specialize as a phytopathologist by combining the subjects entomology and phytopathology. Another possibility is a technological specialization or an agrogeological one.

Those who are attracted to an economic specialization will already have chosen the sub-faculty of tropical agricultural economics in the second part, before the Bachelor's examination. In that case the obligatory subjects for the final examination will be Tropical Crop Husbandry and Tropical Agricultural Economics.

In addition to this, for instance, General Economics and Agricultural Legislation may be chosen as optional subjects.

In many cases the student also chooses combinations of obligatory and optional subjects that require a less far-reaching specialization, which leads to a more general agricultural study. This may be done by choosing, in conjunction with the obligatory subjects Tropical Crop Husbandry and Agricultural Chemistry: Technology and Phytopathology or Agricultural Economics and Agrogeology.

Besides an oral examination in each of the four subjects the student has to hand in a written critical report of the literature on a special problem for each of his four subjects.

It should be mentioned that to be allowed to sit for his last examination, the candidate has to produce evidence that after his second examination (the Bachelor's), he did practical agricultural work for at least six months. This practical work is usually divided into a period of work on a farm, and in a research or advisory institute working for the practical side of agriculture; sometimes also an economical or statistical advisory or planning bureau.

The students of tropical agriculture usually do their practical stage in a foreign country in subtropical and tropical regions. If necessary Government funds provide subsidies in order to meet the considerable costs of travel.

Many of these students do their period in the rice-growing districts in Southern France, Northern Italy or Spain, others go to the citrus belt of Spain, Italy, Algeria or Morocco. A few work in the mechanized rice culture of Surinam, or in the experimental mechanized groundnut culture in North Africa, the oilpalm culture of Africa, the coffee culture in Brazil, or, finally, on the mixed farms of South Africa.

The practical experience gained during this compulsory half-year is enormous, as it immediately follows after the theoretical agricultural study the students make for their Bachelor's degree. Besides, this stage opens the possibility of determining further specialization during the final part of the study. Moreover they learn to adjust themselves in a foreign country and get a routine of expressing themselves in a foreign language, usually English or French.

This half-year stage is usually arranged in such a way that it falls immediately after taking the B.Sc. degree. Upon returning, the study for the final examination commences and lasts for one year and a half. This spell is concluded by the final examination which grants the title of 'landbouwkundig ingenieur', a degree which is equivalent in French-speaking countries to 'ingénieur agronome', and in English-speaking countries to 'Master of Agricultural Sciences'.

On those who possess a certificate of 'landbouwkundig ingenieur' (M.Sc. degree) may finally be conferred a doctorate of agriculture after their defending a doctoral thesis with propositions before the Board of the Agricultural University.

The doctorate can only be obtained after an independent investigation into one of the branches of agricultural science. Consequently this study is a further-reaching specialization than that which can be obtained by a special choice of the examination subjects in the last period of the study for M.Sc.Agr. The difference is, that this latter study warrants that one may develop into a specialist, while the continued study for the doctorate leads to independent research, a contribution of one's own to the knowledge in the department of agricultural science chosen.

Many do not take their doctor's degree until they have been working in this way for years and often after having already had the direction of research work.

Sometimes the study for the doctorate follows immediately on the preceding study, though in this case it is mostly combined with an assistantship.

Before the war almost all the alumni of the faculty for Tropical Agriculture got a job in the former Dutch East Indies. Although, even now, some of them get a managerial position on estates in Indonesia or act as advisers in extension or research for these estates, the number of those who find a position in Indonesia gradually decreases. Fortunately this is counterbalanced by the fact that the programmes of technical assistance to the so-called underdeveloped countries, which programmes for the greater part are in agricultural areas, demand such a number of experts in all tropical

regions that the Dutch M.Sc.Agr. is able to maintain his place in the world.

During the last few years the number of undergraduates at the Agricultural University has varied between 1,000 and 1,200. Since 1945 rather more than 100 certificates of 'landbouwkundig ingenieur' have been conferred annually, of which 20 are from the faculty of Tropical Agriculture. The different subjects are taught by 40 professors, 10 lecturers and 20 tutors, assisted by a scientific staff of 57 persons. Also scientific research in the University and in the 21 autonomous institutes in the domain of agricultural science, established in Wageningen, has expanded at an unprecedented speed of late years.

THE STATE COLLEGE FOR TROPICAL AGRICULTURE AT DEVENTER

The state College for Tropical Agriculture was founded by the Board of Agriculture of the Netherlands in 1912.

The purpose of this college is to provide a thorough education and training for those who prepare themselves to take leading positions in tropical agriculture.

The instruction is intended to cover the practical as well as the theoretical aspects of tropical agriculture, especially for future planters. Consequently both the cultural and the scientific side of the students' training are given the utmost care.

As European planters in the tropics are also the representatives of Western civilization, full care is given to general intellectual and artistic education. In addition to the regular curriculum, musical performances and lectures are given by qualified visitors.

The instruction is directed towards the acquisition of scientific and practical knowledge of the main crops such as sugar, tobacco, rubber, oil palm, coffee and tea, although the smaller ones are not neglected.

Students are admitted after having passed the examination of at least three years secondary schooling and must have the minimum age of 15 years. However, as a rule the age of the first-year students is 18 years, so that, when they finish the course in due time, they are awarded the final certificate at the age of 21. It is desirable then that they take at least another year at a European agricultural enterprise of a practical nature, before they begin their work in the tropics.

A great percentage of the total enrolment of the students does not come from agricultural circles, but originates from the towns. Many of them have spent their youth with their parents on a plantation in Indonesia. The College was founded with the aim of providing well-trained and educated planters for the many estates we possessed in the former Netherlands-Indies, now Indonesia. Most of the graduates were sent out on contract to the East Indies by the large estate companies in Holland, to be engaged on a plantation of tea, rubber, coffee, oil palm, sugar, tobacco, *etc.* By faithful discharge of their duties, they often became managers after some years. Their training and education were and are still such, that after some years of experience they are capable of managing a plantation. As Indonesia is trying to work with its own natives, the opportunities for employment of Europeans have decreased more and more since 1949. In the last few

years the number that found employment in Indonesia was limited to some dozens, whereas the number obtaining a final certificate ranges from 110 to 150 a year.

Procuring employment in tropical agriculture for such a large number entails many difficulties; while there are less opportunities abroad, many of the graduates have been assigned positions in many parts of Africa, in South America, in the Caribbean Islands, in Oceania. Furthermore, we find them as immigrants in Canada, New Zealand, Australia and South Africa. As great stress is laid on the practical side of their training, they are completely qualified to take leading positions in several fields of agriculture.

Though tropical agriculture forms the main part and the aim of the education, the number of additional subjects is very large. In the first two years the students are instructed for two hours a week in carpentry and metal work. The former supplies a background for the course of constructional engineering (graduates should be able to build a house of ordinary construction), the latter forms a basis for better understanding of Mechanics and knowledge of motors, engines and machines.

Much attention is given to chemistry, especially agricultural chemistry. Analysis and mapping of the soil are included in the curriculum.

Laboratory work in chemistry and physics is part of the programme, as is also practical surveying and levelling. The surveying of sloping and hilly ground is of major importance for work in the tropics.

The courses given cover all the general phases of tropical and other agriculture. Specialization in the various cultivations is given in the post-graduate courses, which are open to those who possess the final certificate of the College. There are courses in perennial crops, tobacco growing and in sugar growing and manufacturing. The sugar course is of one year duration, and those having taken it can fill posts as sugar chemists. The other post-graduate courses last for about six months.

Practical agriculture is considered of great importance and instruction in general farming begins in the first year, when the students are obliged to work for a month on a mixed farm. In the spring of the second year of study they must work for six weeks on a general agricultural enterprise, so as to have practice in tilling of the soil, fertilizing and sowing.

Pruning, grafting and inoculating is taught in the College gardens. Hot-houses offer the opportunity for experiments with a collection of tropical plants, and in them we find, of course in small quantities, oil palm, coffee, cocoa, sugar-cane, tea and several other tropical plants.

During the last few years much attention has been given to mechanical methods in cultivation and spraying. The College has a tractor at its disposal so that the students may learn its practical operation.

This is probably the only school in Europe that covers both theory and practice so thoroughly, which is confirmed by W. H. Beckett of the Agricultural Economics Research Institute at Oxford, who on a visit arranged by the British Colonial Office, to study tropical agricultural training, wrote in his report:

'At Deventer, the training over the three-year course is sound in the Agricultural Sciences; liberal in that the Arts, with some sociology *etc* are given attention; and practical. The latter is most important and, with some

exceptions, as the Northampton County Institute or the Ford Agricultural School at Boreham, provides a type of training which British institutions do not, but is of major importance for the under-developed Colonies. These men would be very suitable for work such as cocoa surveys and disease campaigns, and as Production Officers. . . .'

THE INTERNATIONAL AGRICULTURAL STUDY CENTRE AT WAGENINGEN

The law on agricultural education in the Netherlands did not provide for teaching in languages other than Dutch.

As international co-operation became more and more effective after the war, leading to an exchange of staff, students, experts, *etc* in the field of agriculture, and considering the expanded programme of technical assistance of the United Nations and its specialized agencies, more particularly the fellowship programme and the bilateral programmes in this field, one can understand the necessity of extending the possibilities for study on an international basis. For this reason the International Agricultural Study Centre was established in September 1951 at Wageningen, Holland's agricultural capital.

The aim of this study centre is to open the possibility for post-graduate education in one or more branches of agriculture, more especially in the fields of tropical agriculture and forestry; so that foreign students can specialize.

Students wishing to do so can enrol at any time, for instruction is individual—at least when no large groups will be studying the same subject. Every one has a free choice of subjects, both major and minor, and every opportunity will be given to compile a course programme comprising subjects applicable to the student's home country. Instruction is in English, and if enough French-speaking students enrol, in French as well.

The International Agricultural Study Centre is closely related to the Agricultural University, therefore all the facilities of this University are at the disposal of the study centre. The teaching staff is the same, but the style of teaching differs—at the study centre individual instruction is given. Certificates are issued on completion of a progamme.

From the experience gained it was considered desirable to offer facilities to study tropical agriculture in the Netherlands for those not having the necessary background in agriculture. The International Agricultural Study Centre established a department at the State College for Tropical Agriculture at Deventer. Here the system of class-wise education is followed. Because instruction is given on basic problems in tropical agriculture, teaching in classes is preferred. Subjects like physics, chemistry, mathematics, botany, zoology, geology, tropical crops, management of plantations, economics and statistics, cattle-breeding, surveying and levelling, mechanics, constructional engineering, *etc* are taught during a period of three years.

Training of foreigners is separated during the first year because of the use of the English language. It might be to the advantage of those enrolled to follow Dutch classes as well in their second and third year.

The International Agricultural Study Centre consequently offers possibilities to two categories of students:

(1) Postgraduate education at Wageningen—individual training.
(2) Undergraduate education at Deventer—instruction in classes.

However, there is a third and not the least important activity. Starting in 1953, summer courses on specific subjects in agriculture are to be given during a certain period annually. The first one held was on Methods of Agricultural Extension, and a total of 103 participants from 32 different countries attended. It is the intention of the Board of the Study Centre to have a training course on the same subject again in the summer of 1954, thus giving the opportunity to young graduates working in the extension services of the different countries to gain experience in a four weeks' course, including field trips.

The foreign student is no stranger to Wageningen. Many, including students from El Salvador, Egypt, the Gold Coast, Liberia, Burma, Iran and Peru, have already become acquainted with the agricultural institutions there, and fields of study varied from agricultural mechanization to animal husbandry.

With this set-up—postgraduate education at Wageningen, undergraduate courses at Deventer and annual summer courses—the International Agricultural Study Centre hopes to make its contribution towards international co-operation in the field of agriculture.

(*Received September 1953*)

A Short Study of Pepper Culture with Special Reference to Sarawak

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The most important peppers known to the spice trade are produced from the fruits of the vine (*Piper nigrum*, Linn.), and from these berries, black or white pepper can be produced.

Black pepper is prepared by drying the berries in the sun after plucking. The berries for this type of pepper are often plucked unripe but berries which have been shed prematurely and have been damaged are also included. At the time of writing a high quality black pepper is being produced.

White pepper is prepared from almost ripe berries by retting them in water in order to remove the pericarp and then sun-drying them.

Much of the pepper grown in Sarawak is produced by Chinese gardeners. However, the Dayak has not been slow to realize that pepper is a more remunerative crop than rubber and a fairly large acreage is now planted by them. Very few pepper gardens are farmed by Malays.

The methods of cultivation, propagation and culture described in this paper are common to the Malay Archipelago and Indochina.

HISTORICAL

There can be little doubt that the condiment pepper has been stimulating digestions for many centuries. In one of the earliest written records, Theophrastus in the fourth century B.C. records that he was acquainted with two types of pepper, these appear to have been the berries of *Piper nigrum* and *Piper longum*, Linn. (Indian Long Pepper). Pliny in A.D. 77, records that *P. longum* was worth twice as much as *P. nigrum*. According to Gibbon, pepper was a favourite ingredient of the most expensive Roman cookery.

The centre of origin of *P. nigrum* appears to have been the Western Ghats of India. From there it spread to Assam and North Burma presumably by human agency. The exact period at which *P. nigrum* was introduced into Malaysia is uncertain but it is thought that the Hindu colonizers of Java introduced it some time between 100 B.C. and A.D. 600. Pepper trading between Java and China is recorded in A.D. 1200 and Marco Polo in 1280 records having seen pepper in Malaysia.

The trade in pepper from Asia to the Mediterranean was originally in the hands of the great Mohammedan trading nations. With the discovery of the sea route via the Cape in 1490 practically all of this trade was eventually monopolized by the Portuguese and other European maritime nations in the century which followed. Malacca and Goa were then the main centres of the pepper trade.

Figure 1. A well-terraced pepper garden in the Miri District of Sarawak

In the sixteenth century the main producing centres seem to have been Malabar, and along the west coast of India between Cape Comorin and Cananore. Malacca, Sunda, Java and Kedah are also quoted as being lesser producers. English travellers to Siam in the sixteenth century have recorded that pepper was also grown in that country.

Pepper cultivation in Malaysia at this period seems to have been haphazard. It was the Dutch in the seventeenth and eighteenth centuries who brought organized pepper cultivation on a plantation scale into being in Java. During this period the Malayan pepper trade appears to have declined.

It was not until the end of the eighteenth century and early nineteenth century that organized pepper growing came to Malaya. It was then often grown in association with gambier (*Uncaria gambir*, Roxb.). In the middle of the nineteenth century over-production and consequent low prices caused a depression and pepper production fell off. Since that period pepper production has alternately waxed and waned throughout the Archipelago following market trends.

No accurate record exists of the exact period at which organized pepper growing started in Sarawak. Exports of pepper in 1809 from Brunei are said to have been considerable and abandoned pepper gardens in the north of Sarawak were recorded as long ago as 1856. A considerable amount of pepper was grown in conjunction with gambier 70 to 80 years ago, the extracted waste leaves of gambier being used as a form of mulch or manure on the subsidiary pepper gardens.

The cultivation of gambier underwent a decline and practically ceased in 1924. Many of the gambier planters then apparently turned to pepper planting.

Disease periodically ravaged pepper areas to such an extent that after 10 to 15 years of prosperous cultivation it was common practice for gardeners to abandon existing areas and seek ' pastures or hill slopes anew ', trailing the diseases with them. Abandoned areas reverted to ' Lalang ' (*Imperata cylindrica*, Beauv.), the most important noxious grass weed of Sarawak. The amount of land wasted in this manner has been considerable and lalang deserts resulted in many parts of the country.

Violent fluctuations in the market price for pepper from 1923 until 1940 did not benefit this form of agriculture in Sarawak. Speculation was rife and a poor type of planter was attracted to the land. A shortage of land suitable for pepper resulted and many steep hill areas were planted up that would have been better left under natural cover. Shop-keepers and merchants who ' grub-staked ' pepper gardeners at a high rate of interest on the security of the mortgage of the garden were badly hit during depressions as the surrendered pepper gardens died out as a result of neglect.

Most of the pepper gardens died out from neglect during the Japanese occupation. However, considerable quantities of pepper seem to have been hoarded and stored away. In 1947, 1,460 tons of white pepper valued at £363,813 were exported. The Kuching market price at the end of 1947 was £15 3s. 4d. per picul. There was a negligible acreage of yielding pepper vines in the country at this time.

The following table gives an annual account of pepper statistics since then:

Year	*Estimated acreage of pepper planted since 1946*	*Export of white pepper tons*	*Export of black pepper tons*	*Kuching price per ton at 31 December*	
				white	*black*
				£ s. d.	£ s. d.
1948	150	425*	18	21 0 0	19 2 8
1949	500	313*	8	84 11 8	29 3 4
1950	No figures	267	14	94 0 8	47 5 0
1951	No figures	1,160	49	80 5 4	40 9 1
1952	2000	Total for both types 4,013 tons†		54 6 10	41 1 8
1953	3000	Estimated 4,762 tons for both types		—	—

* Probably mainly produced prewar

† 50 per cent of this figure was black pepper

Figures for 1950 pepper exports were low possibly as a result of prewar stocks being almost exhausted. Pepper planting has taken place at such a rate since 1949 that it has been impossible to keep accurate statistics of the acreage planted. In 1950 the Natural Resources Board of Sarawak recommended to Government that in the interests of conserving the natural resources of the country no further alienation of land for pepper should be allowed. This recommendation was accepted. By 1951, export figures showed that the country was almost back to the prewar level of pepper production.

In 1952 prices fell slightly and the small margin between the price offered for white and black pepper throughout that year resulted in an increase in the production of black pepper. The production of this type of pepper is more favourable to those gardeners who do not possess a good water supply which would enable them to 'ret' and bleach pepper berries sufficiently to produce a high standard of white pepper. Furthermore, the production of black pepper from green berries gives a higher yield, nearly 50 per cent, compared with the production of white pepper from a similar quantity of fruit. The labour involved in the production of black pepper is also less.

The forecast of total pepper exports for 1953 is conservative as it is anticipated that the incidence of certain diseases which affected yields prewar and which have again made themselves felt is on the increase. It seems certain that the proportion of black pepper will increase.

BOTANICAL AND VARIETAL

Piper nigrum is a native of the hot humid tropics. At present cultivation is mainly confined to the following broad limits: between the 75th and 115th degrees of longitude and between the 5th degree of latitude south and the 15th degree of latitude north.

The pepper plant is a large, woody, many-branched, climbing perennial vine with luxuriant dark green foliage. The vine can grow to considerable heights up tree support. Small finger-like rudimentary roots which sprout from each node of the aerial stem hold the vine firmly to its support.

It is a shallow-rooting plant, the root system being located within one to two feet of the soil surface. On an average the root system consists of three to six main roots with an extensive network of laterals.

Many pendulous green flower spikes 3 to 5 in. long are carried opposite the leaves. These spikes are covered with a mass of minute white to yellow flowers, up to 150 in number, which, when in bloom give a catkin-like effect. The flowering period is from 5 to 7 days. Flowers can be hermaphrodite or unisexual, though plants bearing exclusively male flowers are sometimes found.

Fruits are baccate, green in colour turning cherry-red when ripe. The fruit is small with a thin soft pericarp surrounding the seed.

Different races of wild *Piper* exist and vegetative propagation by cuttings through the ages has segregated useful varieties. One of the most important varietal characteristics is the distribution of sexes in the flowers. Some plants have a low ratio of hermaphrodite flowers to unisexual flowers and are consequently low yielders. Vegetative selection has thus tended towards plants with heavy yields, that is plants with a very high ratio of hermaphrodite flowers.

No pepper is grown from seed in Sarawak as growth is very slow and seeds do not always breed true. In Indo-China, however, it has been observed that pepper grown from seed is more vigorous and more drought resistant than pepper grown from cuttings; it comes into bearing in 4 to 5 years.

Another important varietal chacteristic is berry size. The writer has noted some correlation with other vegetative characteristics in this respect. Vines with large leaves bear long fruit spikes with large berries. The berries lie in uneven rows on the spikes, fruits tend to ripen evenly but are easily shed. Vines with smaller leaves bear shorter fruit spikes with smaller berries. The berries lie in more even rows on the spike, they do not ripen so evenly and are less easily shed than larger berries. Small berries appear to have a more pungent odour and taste than larger berries.

On an average the small leaved varieties give a higher yield of berries per vine than the larger leaved ones. This is possibly due to the flowers being more dense on the spikes of the smaller leaved type.

Pepper berries contain the alkaloids piperine and piperidine. The pungent taste is due to a resin and the odour to a volatile oil; this oil, containing terpenes, can be distilled from unripe berries.

SOILS

Several wild species of *Piper* are found in the jungles of Sarawak growing on typical jungle soils with a high humus content. Unsuccessful attempts have been made to cultivate *Piper nigrum* on peat soils in this country despite balanced manuring. The cause of failure is mainly attributed to waterlogging. *Piper nigrum* requires a soil which is well drained and free from excessive moisture. With a rainfall in Sarawak of 100 to 200 in. per annum it is practically impossible to drain peat areas sufficiently well to establish pepper on them. It is thought that planting 'hills' 3 to 4 ft. high might help to alleviate the effects of waterlogging on peat soils.

The ideal soil for pepper in Sarawak has been found to be well-drained alluvium with a fairly high humus content. However, well-drained alluvial

soils which are not subject to prolonged flooding and periodic waterlogging are not extensive and are relatively rare.

Practically all the pepper gardens in Sarawak are located on undulating rolling country or on hill slopes of varying steepness. The soils of such terrain are generally composed of heavy reddish-brown clays with a high sesquioxide content. In some cases near the sea coast the soils of these areas have a high quartz sand content and are relatively easy to cultivate.

Pepper gardens planted on steep hill slopes are prone to soil erosion with gullying and consequent vine root exposure. In 1949 the Sarawak Natural Resources Ordinance empowered the Department of Agriculture to take action against gardeners who planted on steep hill slopes without taking some form of anti-erosion measures. Responses to notices to construct anti-erosion works in certain parts of the country have been fairly good and pepper has been planted on terraces.

In undulating country, especially in coastal districts, a sheltered garden with an easterly aspect generally does better than a garden exposed to the elements on a hill top.

MANURES

In the early days of organized pepper growing in Sarawak the extracted waste leaves of gambier (*Uncaria gambir*) appear to have been used as a form of mulch or manure. When gambier went out of cultivation, increased use of a mixture of burnt earth and wood ashes as a fertilizer or soil conditioner was made by pepper gardeners. Leases of land to pepper gardeners in these days were made on the assumption that it took 4 acres of virgin land to keep about ½ to 1 acre of pepper in production for 8 to 10 years. That is, it took about 4 acres of land to supply sufficient topsoil and timber to make this form of fertilizer. The land wastage was considerable and the results of this policy can still be seen in the considerable areas of lalang desert that resulted. Since the war the Department of Agriculture has discouraged this traditional but wasteful practice in favour of balanced manuring with organic or artificial fertilizers. It still goes on to some extent, however, burnt earth and wood ashes being mainly used as a dressing for young vines in their initial years of growth.

It has been found under Sarawak conditions that pepper requires a high plane of well balanced nitrogenous manuring if fruit production is to be kept at an economic level.

Normally pepper vines are not allowed to come into bearing until 2½ to 3 years after cuttings have rooted. Rates of application of both organic and artificial manures can be regulated accordingly.

Sarawak is fortunate in having several large but not inexhaustible phosphatic guano deposits. An analysis of a typical sample is given below:

	per cent	
Moisture	41·97	
Loss on ignition ...	58·11	On a moisture-free basis
N	6·53	On a moisture-free basis
P_2O_5	8·07	On a moisture-free basis

This fertilizer is used extensively by pepper gardeners throughout Sarawak, but unfortunately the rate of extraction has to be controlled and there is

not enough to go round. Consequently gardeners have to use local organic fertilizers such as prawn refuse, fish refuse and bean cake, alone or in conjunction with guano or burnt earth. Analyses of typical samples of these manures are:

Analysis	*Prawn refuse per cent*	*Bean cake per cent*	
Moisture	60·31	8·82	
Loss on ignition ...	48·40	86·32	On a moisture-free basis
Nitrogen	4·07	0·91	
P_2O_5	7·23	1·85	
K_2O	2·21	2·56	
CaO	3·45	0·43	
NaCl	29·94	—	

In these days of high prices when speculation is rife, pepper gardeners are trying, with the use of the organic manures mentioned above, to ' cash in ' by forcing their vines to come into bearing 1½ to 2 years after cuttings have been planted. In such cases it has been noticed that whilst a fairly heavy crop is obtained in the initial and second years of fruiting, production in subsequent years frequently undergoes a marked decrease, yields being reduced by two-thirds to three-quarters. Plant health is also greatly impaired and it is now obvious that a considerable area of pepper in Sarawak is going to be affected by ' Sudden Death ' disease. This, the writer suspects, may be aggravated by the high rate of nitrogenous manuring and by the high content of sodium chloride in the prawn refuse used. The following rates of application of these organic fertilizers are common amongst pepper gardeners:

Guano. Up to 5 lb. per vine applied four times per year after the vine has commenced to fruit.

Prawn refuse and fish refuse. 2–5 lb. per vine applied three to four times per year. Yielding vines are generally given more with a booster application after harvesting has been completed, about July or August.

Bean cake. 3–5 lb. per vine applied three times per year.

The more skilled and not so speculative gardeners coordinate manuring and pruning in such a way as to give maximum growth and fruit production.

Increasing quantities of balanced artificial fertilizer mixtures and of a semi-organic mixture based on blood and bone meal are now being imported by some local firms for sale to gardeners. Gardeners have shown considerable enterprise in using these mixtures, which helps to meet the large unsatisfied demand for guano.

The Department of Agriculture has made field trials with various methods of manuring and whilst it is too early yet to give definite information the following points are manifest:

(*a*) Manuring should commence a month to 6 weeks after planting vine cuttings. Rates of application of manures should be regulated according to vine growth.

(*b*) Placement of fertilizers within 12 to 8 in. of the vine stem every 6 to 8 weeks gives better results compared with top dressings of similar fertilizers applied at similar intervals.

(c) Inorganic manures work out cheaper per unit when compared with organics such as prawn refuse, bean cake and fish refuse.

(d) Manures should be applied regularly, a little at a time rather than in large forcing dressings two or three times per year.

(e) Responses to small dressings of sulphate of ammonia, about 1 oz. per vine, applied as a top dressing are increased if it is used in conjunction with a basal ' placement ' treatment of phosphatic fertilizer.

(f) Sarawak soils generally respond to phosphatic fertilizers, more so if they are applied by placement methods in conjunction with lime. ' Placement ' dressings of rock phosphate at a rate of 4 oz. every 2 to 3 months have given good results.

(g) Pig manure alone has been tried and gives good results if well cultivated into the soil round the vine at the rate of about 2 lb. every 2 months.

(h) There are indications that small dressings of muriate of potash, up to 2 oz. applied every 2 to 3 months, improves the health and vigour of vines.

(i) Responses are good to dressings of guano, up to 2 oz. per vine being applied by placement methods every 2 to 3 months. Higher rates up to and over one pound every 3 months have been tried, but this is thought to impair the subsequent seasons' yields and the health of the plant.

CULTIVATION

Much of the present pepper in Sarawak has been and still is being planted up on old pepper areas which were abandoned 20 to 30 years ago. Such areas are denuded of jungle and have reverted to lalang grass (*Imperata cylindrica*). Few gardens have been established on areas of virgin land since 1946. The majority of gardeners thus find considerable difficulty in making their traditional burnt earth soil conditioner due to the absence of adequate firewood.

The average size of a pepper garden in Sarawak is about half an acre, that is the area most convenient for a family to handle by themselves. Planting ' hills ' are spaced 7 to 8 ft. apart in the row and 7 to 8 ft. between the rows. This gives a stand of 850 to 880 vines to the acre.

The area to be planted is dug over with a changkol (a digging hoe) three to four times within a period of about 3 months. This cultivation is preferably confined to the driest part of the dry season, between March and August, in order that the very persistent rhizomes of the lalang grass may be thoroughly cut up, desiccated and killed.

After this cultivation the garden is lined out with temporary stakes to the distances detailed above prior to earthing up of planting ' hills ' and planting out.

Initial cultivation and planting-out practice vary from one area to another. Sometimes planting ' hills ' are mounded up and cuttings planted after the first or second cultivation of the area. The subsequent three or two cultivations are then carried out between the planting ' hills '. Cuttings can also be planted on the flat, planting on ' hills ', however, appears to be more common.

A fairly high proportion of burnt earth and wood ash is mixed with the soil of the planting ' hill '. The ' hill ' is mounded up each year after harvesting has been completed, topsoil being scraped from between the

rows to do so. Invariably insufficient soil is obtained from between the rows and topsoil is stripped from areas close to the garden; this takes place about September. After 4 to 5 years the mounds reach a height of 1 to 2 ft. with a base of 2 to 3 ft. and in this way the basal nodes of the vine stem and shallow basal roots are kept covered.

It is difficult to convince gardeners of the need to cover up the bare strips of soil between the vine rows in order to prevent soil erosion ; they persist in clean weeding these strips. Mulching between the rows with cut and dried lalang grass has been tried on agricultural stations and has proved to be very satisfactory, but there is unfortunately a fire risk during dry weather. Leguminous covers have also been tried but it has been found that they are too vigorous and if not regularly slashed back they smother young vines. Attempts are being made to encourage planting on the contour, on platforms, and the construction of contour check bunds and silt pits.

Some pepper gardeners interplant the rows of young pepper with quick-growing cash crops. This is unfortunately not a common practice. Interplanting of mature pepper is not possible as inter-row cultivations will damage the shallow root system of the vines.

It seems reasonable to advocate a much wider planting of pepper between the rows, say up to 15 ft. apart. This would allow for intercropping, would reduce erosion if carried out on the contour, would minimize the spread of root disease and also balance to some extent the one crop policy of the pepper gardeners.

PROPAGATION

Pepper vines are invariably propagated by cuttings, and these cuttings are best taken from the terminal shoots of immature vines under 2 years old.

Cuttings should be about 2 ft. in length with 5 to 7 nodes, each node being 3 to 4 in. long.

Before the cutting is taken from the vine the terminal bud of the selected shoot should be broken off. The leaves and small branches between the third and seventh nodes from the apex of the shoot should be stripped off.

After about 10 days, when regeneration of the terminal bud is evident, the shoot should be cut below the seventh node and the cutting removed, care being taken not to damage the finger-like aerial roots which sprout from each node and which hold firmly to the support post.

Cuttings can be planted out straight away on to planting ' hills '. The stem of the cutting should be planted obliquely, not deeper than 4 to 6 in. with 3 to 4 nodes below ground level. Cuttings should be located to the east of the temporary planting stake. Planting can be carried out at any time, the onset of the wet season, however, appears to be the most popular period.

After cuttings have been planted they should be well shaded as the young leaves are very tender. Frequently fern fronds of *Gleichenia spp.*, Smith., are used to provide shade.

The leaves and branches of the top three nodes of the cutting are left and trained up the temporary stake. The cutting is allowed to develop a main shoot from the apex, and two lateral shoots, one from each of the second and third nodes; these shoots will later form the three main stems of the vine.

[illegible] CONCLUSIONS

[illegible]

[illegible]

[illegible]

The canopy leaves within about 2 ft. of the apex of growing vines are never plucked until the three main stems have reached the top of the support posts.

On old vines over about 5 to 6 years little plucking is carried out other than the removal of leaves growing on small tertiary branches.

PESTS

Insect pests on the vine can be relatively easily controlled using the older types of insecticides such as derris decoction, tobacco decoction or proprietary brands of concentrated nicotine. Under Sarawak conditions it has been found that spraying rather than powdering is the better method of applying pesticides to the aerial parts of the vine.

Both B.H.C. (Agrocide) and D.D.T. types of pesticide are very effective in controlling pests. The organic phosphorus compound *Tepp* is becoming popular amongst pepper gardeners, it is more effective than concentrated nicotine and is cheaper.

Some of the insect pests of pepper are detailed below with methods of treatment which have been found to be effective against them.

Root Pests

Eelworm (*Heterodera spp.*). Frequently found to have infested root systems of vines affected by a condition known as ' Sudden Death ' disease. Possibly a general parasite of pepper root systems. Control is difficult as pepper is a long term crop and no crop rotation is possible. French authorities suggest heavy mulching as a possible control.

Termites (*Coptotermes curvignathus*, Holmgr.). Have been noted in some isolated cases to have invaded root systems of vines affected by ' Sudden Death ' disease. Periodic root inspections and removal of dead and rotting material in the vicinity of the vine root systems is advocated, also treating the infected area with soil fumigant. The importance of thoroughly stumping the garden area before planting is emphasized.

Stem and Leaf Pests

Giant African Snail (*Achatina fulica*, Fer.). Sometimes attacks stems of newly planted vine cuttings and kills them. General control throughout the garden area using *Meta Fuel* baits is effective.

Beetles (*Pelargoderus bipunctatus*, Dalm.). The larva of this beetle can attack the vine stems and shoots. Usually seen on unhealthy vines. Can be controlled effectively by spraying with Gammexane dispersible powder solution.

Bugs (*Helopeltis antonii*, Sign.). Have been noticed to cause die-back of shoots and buds and deformation of leaves in isolated cases. Not a serious pest though incidence thought to increase in the wet season. Spraying is an effective deterrent.

Thrips (*Gynaikothrips chavicae*, Zimm. and *Gynaikothrips crassipes*, Karny.). Sometimes cause galls on pepper leaves in the dry season. Not serious.

Caterpillars (*Eumeta hekmeyeri*, Heyl.). Can cause some damage to vine leaves, not serious. Spraying is an effective deterrent.

Scale insects and mealy bugs of various species. These suck young shoots causing die-back and if not controlled can spread to berries. Incidence

increases during dry season and if not checked in the early stages can cause considerable damage. Can be easily controlled by spraying with *Tepp*.

Fruit Pests

Pepper Weevil (*Lophobaris serratipes*, Mrshl.). The adult eats round holes in the fruit often causing them to be shed prematurely. This pest can cause considerable damage to the pepper crop if control measures are not taken when gardens are setting fruit and fruit is ripening. Weekly spraying is carried out by many gardeners while gardens are fruiting, this measure is entirely effective.

Bugs (*Elasmognathus hewitti*, Dist. and *Dasynus piperis*, China.). Suck the young pepper berries, discolouring them and causing premature fruit shedding. Controlled by regular spraying whilst the garden is fruiting.

DISEASES

Fungal diseases on the stem, foliage and fruits of the vine have been found comparatively easy to deal with by regular spraying using the fungicides mentioned below. Some difficulty has, however, been encountered during the wet season as little fungicide remains on the foliage and vine stems.

The various fungal diseases encountered on pepper in Sarawak are detailed below with the methods of treatment which have been found to be successful under Sarawak conditions.

Fomes lignosus, Klotzsch

This fungus attacks the main stem and also the roots of the growing pepper vine.

It would appear that the main reservoir of infection is located in old pepper posts which have been salvaged from long neglected gardens and re-used. Rotting tree stumps and roots are also sources of infection.

Young shoots and leaves of the vine often do not show symptoms until the disease on the main stem has reached an advanced stage. A white rhizomorphic mycelium which originates on the support post spreads rapidly to the vine stem which, when initially attacked, remains firm but turns dirty grey in colour. If the disease is not checked in the early stages the vine stem rots away to a wet sappy mass.

If the disease is detected in the early stages and the vine stem cut 6 in. to 1 ft. below the lowest limit of spread of the disease and close to a lateral branch the vine stands a good chance of regeneration. The cut on the vine should be treated with *Agrosol* solution and the old support post either replaced by a new one which has been treated with a 2 per cent copper sulphate solution or it can be scraped and painted with copper sulphate solution. The truncated vine stem and stems of remaining shoots should be sprayed with 2 per cent copper sulphate solution.

Ganoderma lucidum (Leyss ex Fr.) Karst.

This fungus can cause a serious root rot of pepper vines and if not detected in the early stages it can cause heavy losses. The main source and reservoir of infection lies in old tree stumps.

A rhizomorphic mycelium forms a continuous rubbery skin which encloses the vine roots. In the early stages the mycelium is a dirty white in colour,

the root itself remaining firm. In the later stages the mycelium changes to a dark red colour and the root rots away to a wet sappy mass.

In the control of this disease early detection is essential. Collar inspections of vines should be carried out regularly, soil dug away from the collar and a short length of root system exposed.

If the disease is detected in the early stages the root systems of infected vines should be laid bare and rotten roots with adhering mycelium removed and burned. The whole root systems should be painted or sprayed with a 2 per cent solution of copper sulphate. Before the root system is filled in care should be taken that all broken pieces of mycelium are removed.

Cephaleuros parasiticus, Karsten

Pre-war this disease which was known locally as 'Black Berry' caused serious losses. No serious cases have so far occurred since then.

This parasitic brown alga attacks the skin of young berries on the fruiting spike, the berries become covered with spots composed of tufts of fine yellow hairs. The berries turn black and are shed prematurely and can only be used for the preparation of black pepper. This brown alga can also attack cloves and rubber, but it is not a virulent disease of these crops and it does not cause serious damage.

If serious outbreaks of this disease do occur it is anticipated that effective control of it can be maintained by the use of modern copper fungicides such as *Perenox*.

Sudden Death Disease

This is a virulent complex root disease of pepper the incidence of which has undergone a dramatic and explosive increase in the last twelve months. A disease with similar symptoms is reported from Indonesia and Indochina. The disease was known pre-war but its virulence was low and it apparently caused little damage. Attempts at control were made by gardeners themselves who carried out a primitive form of root sanitation. Disease symptoms being recognized early, the root system was opened up and almost the whole of it amputated leaving only a few small lateral roots close to the collar of the vine. These remaining roots were sometimes painted with slaked lime. The vine itself was cut back to about three feet high. This drastic treatment sometimes resulted in the vine growing a new root system. Recovery, however, appears to have been rare and recent trials conducted along similar lines have had no success.

Specimens of diseased roots have recently been sent for specialist examination. They confirm that the root systems are heavily infected with eelworm (*Heterodera spp.*). This is possibly only a secondary infection associated with a primary fungal or bacterial infection or deficiency disease. Other evidence points to physical damage to the root system having a trigger effect on the incidence of the disease. Excessive nitrogenous manuring and manuring prior to or during wet weather appear also to favour onset of the disease. The disease does not seem to be confined to any particular soil conditions.

A leaf wilt is often the first indication of the presence of this disease. In some cases no leaf wilt is evident yet the root system is found to be in an advanced state of decomposition on excavation. Leaf wilt commences at

Figure 2. Often the first indication of 'Sudden Death' disease. Leaves of the vine on the left have turned yellow prior to wilting

Figure 3. A main root of a vine affected by 'Sudden Death' disease, showing the relatively sound exterior but blackened vascular system

the base of the vine and progresses upwards. It can in some cases be confined to the top of the vine. A rapid leaf fall follows the initial wilt and the remaining leaves are chlorotic and in some cases are blotchy and black, fruits wither and shrink and are shed. A rapid die-back of the vine follows.

Once a plant has become infected there seems at present little hope of curing it. Nor are there any adequate control measures that one can take to prevent its spread to adjoining vines.

'Sudden Death' disease is reported to be spreading in pepper growing areas on Singapore Island and in the Federation of Malaya and it is possible that in the near future this disease will become a severe limiting factor to pepper cultivation in the Archipelago.

Possible Virus Disease

A chlorotic mottling and distortion of leaves with poorly developed shoot systems is sometimes encountered. Yields from vines affected by these symptoms are said to be reduced. The more skilled gardeners confirm that these symptoms are perpetuated by vegetative propagation.

Possible Deficiency Diseases

Various foliage symptoms of possible deficiency diseases can be seen on those pepper gardens which are located on the poorer types of soils, especially those with a high quartz sand content.

HARVESTING AND YIELDS

In a well managed garden vines are not allowed to bear many flower spikes until they are over 2 years old. It takes about 5 to 6 months from the emergence of the flower spike and about 4 months after flowering to the actual ripening of the berries. The first harvest will only take place 2½ to 3 years after vines have been planted, by that time vines should have reached the top of their 10 ft. support post.

The entire fruit spike is picked when several of the berries on the spike have turned cherry red in colour, the majority of berries on the spike still being yellow or green. Picking at this stage avoids serious losses by fruit shedding and bird damage whilst giving relatively plump berries, it is also said to give pepper corns with a more pungent odour.

In Sarawak there appear to be two rather indefinite fruit flushes between May and August. Vines are picked over once a week during the harvest period. The fruit flush in July/August appears to be the heavier.

Pickers use tripod ladders to reach those spikes that cannot be reached from the ground and care is taken not to damage the tender vine branch systems.

Shed and damaged berries which have fallen to the ground turn black after a few days. These are collected and sun-dried to produce black pepper.

Towards the end of the harvest period vines are stripped of all fruiting spikes and the resulting ripe or unripe fruits are sun-dried to produce black pepper. This practice is carried out in order to ensure that the vine will come into bearing and fruit evenly at the same time next year. After this operation the vine is stripped of all but its branch terminal leaves.

Yields of pepper are variable and are entirely dependent on management and manuring. It is thus difficult to give exact figures for age/yield correlations, trends only can be indicated.

The following table gives a rough guide to age/yield trends:

Age of Vine Years	*Yield of Vine Lb. 'Green Pepper'*
1, 2	Nil
3	$2\frac{1}{2}$–4
4, 5, 6, 7	8–13–20 increasing with age
8 — 12 — 15	About 4–5 decreasing with age
20 — 30	Said to be almost nil

Most gardens probably become worked out and uneconomical between 12 and 15 years of age.

It is reckoned that 100 lb. of newly picked green pepper will give approximately 25 lb. of dry white pepper or 37 lb. of dry black pepper after processing.

PREPARATION

The fruit spikes and berries are first lightly crushed underfoot to loosen the berries from the spikes. They are then put into sacks which are left to soak or ret in a pool or stream of running water for 7 to 10 days. This is done in order to remove the pulpy pericarp from the seed proper. Slowly running tepid water gives the quickest decomposition. Stagnant and dirty water tend to discolour the pepper corns.

After 7 to 10 days when the skins have become sufficiently rotten, the berries are emptied from the sacks into wooden tubs partially filled with water where they are again trampled underfoot and agitated in order to loosen the stalks and rotten skins.

The wet mass of pepper corns, skins and stalks are then alternately washed and rubbed by hand in sieve-like baskets, water, skins and fruit spike fragments filtering through leaving clean peppercorns.

After final washing the peppercorns must be dried quickly otherwise they will discolour. The peppercorns are spread on mats and sun-dried. Drying takes about 3 to 4 days. A rough indication of the correct degree of dryness is indicated by the corns being difficult to crack between the teeth.

Underdrying causes discoloration of the corns and a certain loss of flavour. The finished product should have a moisture content not exceeding 10 per cent if deterioration in storage is to be avoided.

Black pepper is prepared from unripe berries which have been shed or slightly damaged. Such berries are sundried for 3 to 4 days, the skins turning black and crinkly.

The berries are then rubbed by hand to separate stalks and fruit spikes which are removed by winnowing. With present small price margins between

black and white pepper much of the crop is now being processed as black pepper.

A better method of preparing black pepper, especially in these days when good prices are being offered for heavy grades, is to scald the berries in boiling water for a short time, then to sun-dry them. This gives the product a more uniform colour.

White pepper can also be prepared from black pepper by soaking the latter in tanks. When the pulpy pericarp commences to swell and disintegrate the berries are processed by decorticating machinery. The chief difficulty in this process is to judge the correct moment to stop decortication. If carried too far it removes the white skin of the seed coat and exposes the dark coloured tegument and the desired effect is lost. White pepper prepared in this way is, however, frequently discoloured.

ACKNOWLEDGMENTS

The writer wishes to acknowledge information supplied by R. W. R. Miller, Director of Agriculture, Sarawak, and K. E. H. Kay, Agricultural Officer ; and to make acknowledgments to F. J. Harper, Deputy Director of Agriculture, for helpful criticisms in the final preparation of this article. Also to N. F. Robertson, Lecturer in Plant Pathology, Botany School, University of Cambridge, for criticism of the manuscript and advice on the sections on pests and diseases.

(*Received September 1953*)

REFERENCES

Hakluyts Voyages .
DALTON, G. (1912). ' Pepper growing in Upper Sarawak ', *Sarawak Mus. J.*, **1,** No. 2
RIDLEY, H. N. (1924). ' The Flora of the Malay Peninsula ', **3,** Apetalae. London
HUTCHINSON, J. (1926). ' The Families of Flowering Plants ', *I. Dicotyledons*, London
LAN, J. (1928). ' Les plantes indochinois de grande culture ', Première Partie, Plantes alimentaires. Imprimerie d'Extrême—Orient, Hanoi
DAMMERMAN, K. W. (1929). ' The Agricultural Zoology of the Malay Archipelago ', Amsterdam
BURKHILL, I. H. (1935). ' A Dictionary of the Economic Products of the Malay Peninsula ', Governments of the Straits Settlements and F.M.S.
MACMILLAN, H. F. (1946). ' Tropical Planting and Gardening ', London
ONG KEE HUI (1949). ' The Pepper Industry in Sarawak ', *Sarawak Gaz.*, **75,** No. 1092
KAY, K. E. H. (1949). ' Pepper Planting in Sarawak 1947/1949 ', *Sarawak Gaz.*, **75,** No. 1100
SANDFORD, H. (1952). ' Pepper in Sarawak ', *Malay. agric. J.*, **35,** No. 4
BARAT, H. (1952). ' Etude Sur le dépérissement des Poivières en Indochine', *Arch. Rech. Agron. au Cambodge, au Laos et au Vietnam*, No. 13
Sarawak Department of Agriculture Annual Reports, 1947, 1948, 1949, 1950, 1951, Kuching
Annual Reports on Sarawak, 1949, 1950, 1951, Kuching
MILLER, R. W. R. (1953). ' Disease Threatens Sarawak Pepper Industry ', Kuching

The analysis of Prawn Refuse and Bean Cake tabulated on page 46 was carried out in the Lutong laboratory of Sarawak Oilfields Ltd.

The Need for Enclosure and Land Resettlement in Nigerian Agriculture

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Individualization of holdings of agricultural land is a thing of comparatively recent development in many tropical areas. Such a tendency has been unconsciously encouraged in such group schemes as the 'corridor settlements' in the Belgian Congo, the Gezira scheme in the Sudan, and even in more localized schemes like the Niger project in Nigeria, the Shendam scheme and the Calabar-Bamenda settlement scheme. Group in this context does not import communal nor has it any foundation in that community of rights which the participants in these schemes formerly shared in their several homes. The fact cannot be disputed that an element of disturbance follows these new group schemes if communal rights throughout the country are considered as a whole. For example, a participant who comes from Kontagora and accepts plots of land in the Niger scheme, not only vacates a right in his community in Kontagora, but also creates or assumes a new right in the area of the Project. There are thus two disturbances, one negative, the other positive. A far more radical disturbance of closed community land rights is the case in which a farmer, in spite of himself and of his immediate lineage group, seeks to cultivate a piece of land occupied by that lineage group and farm it along his own lines without interference from his own kinsmen. Thus in an Ibo village, where land was at one time in communal ownership and redistributed each year at the beginning of the planting season, a farmer suddenly brushes aside all interference from chief, father, or uncle, and literally closes an area as his own private possession; or among the Tivs of Benue Province, where administrative officers are occasionally called in to redistribute land, a farmer takes precisely the same step as the Ibo individualist.

The question therefore is, why do individuals who barely a hundred years ago tended to own farming rights on a loose communal basis, and respected traditional land customs, suddenly want to own and possess their plots? Most tribes in Nigeria today are tribes in name not in composition. If we take the Ibo tribe as a classic example of an area where individualization of holdings has tended to assume a hardened character, we may discover why the phrase 'Ibo tribe' is not an accurate description of the provinces occupied by those generally called Ibo. As far back as the early eighteenth century, there had been a series of migrations from various directions into what was, otherwise, the Ibo Reserve. The Onitshas crossed the Niger; the Arochuku war lords and slave dealers overran practically all the territory between the Niger and the River Cross and established over thirty settlements. It was not uncommon to meet a true Ibo who called

himself Aro just to share in the advantages or protection which that name offered; and when a true Ibo became an Aro he could not be expected to respect his former traditions. He had *ipso facto* repudiated them and embraced the conventions of the immigrants. Communal ownership was a rare occurrence among all intelligent races; and the Aros and Onitshas are entitled to that description. In what would appear to be closed family rights, there was still a marked degree of individualism before the advent of the British. There are instances in Okigwi Division of Owerri Province, and Awka Division of Onitsha Province, where certain Aro individuals have recently been forced to surrender land acquired before 1879 because of faulty conveyance perhaps, and yet members of the families of those individuals retained, in fact, land acquired contemporaneously.

But there is more than that. A new form of commerce was introduced by the slave trade and many Ibos suddenly found themselves rich in brass rod currency or cowry shells. It is easy to see how the intelligent rich disposed of their new wealth. The Ibo weakness to have a large entourage impelled many rich men to buy slaves, establish them on the land and turn them into farmers; or to marry wives, each of which events meant new lands bought from the less intelligent or more indigent neighbours. By practice and custom, on what a man has bought with his own money, the community has no claim.

It is not clear to what extent the slave trade fostered any individualization of real property among the Yorubas, but the evidence of a form of communal ownership of land in most Yoruba communities shows that the trade effected no radical change; for, unlike the Ibo area, Yorubaland was until recently a cockpit of intertribal wars. The Binis from the East, the Nupes from the North, converged on an area already torn by internecine strife between the Ileshas, Oyos, and Ibadans. All that can be said with a fair degree of precision is that there arose many petty kingdoms accordingly as any war lord was able to establish his authority over his comrades. Land would at first be under a strong central control, but as political refugees sought sanctuary under the war captain, his land would tend to expand and soon fall under the administration of his lieutenants. Thus arose the patch-work of lineage groups and its conflicting loyalties, among the Yorubas, developing into a strong family rather than community ownership of land. To-day descendants of these war captains and their lieutenants still do not view individualization of holdings with complete approval. A young 'son abroad'—the familiar description applied to clerks in townships—who was watching the proceedings of the District Council in his own home, Ikole, Epiti Division, aired the view, when a land dispute was being discussed, that if the land was sold it must pass to the buyer. The old councillors would hear no such thing. Why was there this conflict between the two worlds? The answer is mainly psychological. First, the growth of cosmopolitan towns. This development is something new in Nigerian life and its influence is marked by a degree of individualism. The last war may be regarded as a clearing-house for ideas, especially in respect of money transactions; and it drove a wedge into the old relationship between individual and family. There was, during the war, an insidious infiltration of Americanism into urban life both in its social and economic spheres. It

came through films and cheap literature on war propaganda. Because of its glitter and absolute disregard for the conservative, this Americanism appealed to the youths more than the dour, but more wholesome, British influence. This development struck at the very foundations of village traditions and customs, for young men when they returned to the village after war service or a spell of trading in the city, began to regard personal property from a new perspective. Secondly, the new education. Every village or town pupil knows that he must depend on his own private efforts to pass his examinations. The missionaries too have introduced an order of merit to the pass list, and many an African pupil would refuse to help his mate lest he take a second place to him. The child is, of course, the father of the man. Thirdly, the new religion. The introduction of a Supreme Deity, ready to punish (or forgive) the individual, not the community as the old gods do, must necessarily divorce individual sentiment from village conventions and make the individual no longer a slave to tradition and communal conscience. Fourthly, the new political habits and fiscal policy. The individual must pay his tax or in default suffer the consequences himself. Under adult suffrage, a man must vote according to his own conscience (a thing unheard of in the old days) and receive no dictation from anyone. Other influences, mostly psychological, leading to a disruption of communal life, can be enumerated in any social climate in Nigeria, and the result tends to be that the responsibility for progress is shifting from the community or family unit to the individual. Already, in the more advanced communities, this sense of independence is asserting itself in such serious forms that first sons no longer feel much obligation in bringing up or training their younger brothers and sisters. This is the hard core of individualism against which communal ascendancy has been struggling during the past ten or more years. It is only a matter of time before the latter becomes past experience. Yet, in the interest of our national solidarity, a compromise must be reached as soon as possible, so that the steadying influence of our traditional heritage may guide and control the progress of individual enterprise.

CHANGING LAW AND CUSTOM

In discussing the question of enclosures in Nigeria, it is hardly possible for us to escape touching upon native land tenure in its traditional context. The introduction of English legal ideas into native judicial circles has tended to complicate a situation notorious for its shifting character. However, there are subtle similarities between the English idea of land ownership and the Nigerian concept; about which, more hereunder. At this stage, it is necessary to trace those local similarities in the Nigerian *corpus juris* relating to land. It must be admitted that we have had the benefit of English law, from those decisions made in British courts in West Africa and in England on cause or matter from the West African countries falling within the jurisdiction of English law. To trace those similarities in local traditional systems of tenure, we must classify the rights residing in a loose communal ownership. The British courts referred to above have effected a separation of rights, judicially, so that the separation has acquired, in places, the force of law. Before we return to the judicial precedents set in the Courts, let us

examine the word ' communal ' in the native Nigerian context. The Ibo word ' Oha ' (Union dialect) cannot be adequately translated by the English words ' communal ' or ' public ' although it has a subtle connotation of these words in the sense that communal or public implies a community of individual interests. Thus in abstract law, the vestitive right of the Ibo community as a *quasi* corporation sole does not imply a divesting or alienation of the individual rights. The same can be said of the Yorubas. Thus, in Sule Giwa and others versus Alashe (Yombas) a chief had forcibly broken into the enclosed land of the appellants on the ground that as chief he was entitled to a sole administration of that part of the communal land so enclosed: Held, by Smith, C.J., that such a position (*i.e.* of chief) only carries a certain social status and distinction among his fellows but no authority beyond that of any other private person ' more especially as much as certain pretensions have recently been advanced by persons calling themselves white-capped chiefs, to control over land in the lawful and beneficial occupation of persons owing no rent or otherwise to them '.

There is a striking similarity between the Gold Coast ' stool ' lands and the communally owned lands of Nigeria in the sense that no single individual, chief or citizen, has had an indivisible and exclusive title to the whole of them; yet, nothing in its character prevents any section of the stool land from lapsing into private ownership. Thus in the famous case of Lokko versus Konklofi (Gold Coast, 1907): Held, by Griffith, C.J., that the occupation of part of the stool land ' had been of such continuance and of such a character that the land must now be deemed to be the property of Konklofi '; and the inter-pleader action of the local chief, that the stool had a reversionary right to the land, failed. This concept of a community of individual rights and interests over communal land may further be illustrated by citing the land practices of one northern tribe in Nigeria. Every Tiv feels that he has a right to sufficient land and his fellows concede that. To him boundaries are unmarked except during actual periods of cultivation and every land dispute is in fact a boundary dispute. A Tiv chief has been heard to say, ' we do not believe in boundaries; we believe in arguments '. Thus an undercurrent of individual investitive rights runs through the whole fabric of community rights and titles to ' public ' lands in Nigeria, but nothing in such individual investitive rights gives them the essential character of the English fee simple absolute in possession.

We will now return to the similarities between the English attitude to land ownership and the Nigerian concept. In English law of real property, it is an unchallenged assumption that ultimately the Crown owns all the land. Thus in abstract law, seisin in the Crown connotes a remote ownership. A series of events may to-day cause land, freehold or otherwise, owing to failure of blood or other reasons, to be declared *bona vacantia* and the reversionary right of such property in the Crown may not be lightly disturbed. Communal ownership in Nigeria must be looked upon as a seisin, a kind of remote ownership differing little from the English concept, although the intervening rights between the individual and the community are not exactly the same as those between the English owner and the Crown. The crucial question is, can an enclosure movement arise out of the relationship between the Nigerian form of seisin and the individual in the same way as it did between

the English sense of seisin and the enclosing landlord or tenant? For our purpose the answer must be in the affirmative. This is a question both of law and of history. Now before enclosure appeared in England, the law took cognizance of those events in which the individual tenants of the great landlords gradually converted certain feudal services or incidents into money payments. In this way arose copyhold and leasehold tenures, more deeply emphasizing the individualistic trend in real property ownership. Now, in Nigeria, customary incidents are being converted into money payments in certain areas. The Yoruba ' Isakole ', an incident falling mostly on strangers, is taking the form of money payments instead of stipulated produce ' tithes ', such as so many hundredweights of cocoa, or pounds of palm oil and kernel. What is the difference between a money payment and a ' tax ' in the form of produce? The former gives a freer hand to the occupant in the matter of what he should grow on the land demised to him; but the latter implies that he must grow cocoa or palm trees as ancillaries to whatever he chose to grow on his farm. In legal parlance, the consideration has changed in form, and custom gradually gives way to contract. Yet in many areas money payment is considered, quite understandably, as an outright purchase, however that payment is unrelated to the economic value of the land, for perhaps in these parts the produce contributed as ' tax ' to the community head may be so scarce, for example, palm oil in parts of Ekiti Division of Ondo Province, that the person to whom the produce tax is paid may look on it as a lucrative investment in the market of that particular produce and a fixed money payment may, in fact, be smaller than the proceeds from the stipulated customary tax if and when the produce is traded in times of boom. There has thus entered an element of speculation into customary incidents, a vicious source of trouble in the matter of chieftaincy disputes, especially where no hereditary chieftaincy exists, for a new chief not in the family of his predecessor may interpret local custom in his own way and fix ' tithes ' at will. But there is more than that. If it must be acknowledged that no chief or person in like capacity owns communal land but merely supervises the administration of that community of interests residing in communal land, it would appear that, in the presence of other compensation for the chief's services, for example, salaries from local Treasuries, whatever accrues from those rights must go into the community chest. This seems to be the development in Bunyoro, Uganda. Furthermore, if in England, as we have seen, the Crown is the fountain source from which all rights over land ultimately devolve, and what is more, gives a certain uniformity of interpretation to rights and titles throughout England, might we not attempt to separate from the *corpus juris* relating to communal lands in Nigeria that denominator common to all the country, a viable authority above politics and any individual, chief or citizen, capable of giving a uniformity of interpretation to rights and titles over land throughout the country?

REQUIREMENTS IN NEW LEGISLATION

The enactment of new laws relating to land falls within the authority of the legislature of the land. This implies that it is the duty of the legislature as representatives of the people to study the problems relating to land tenure with a view to finding out whether the old laws are unable to support the

changing conditions of the times. In England the Law of Property Act 1922 introduced many sweeping changes into the land law of the realm which had lasted for almost six hundred years. It is for the legislature of Nigeria to study the country's land problems and effect changes wherever necessary. It is difficult to foresee any radical change, but a modernization of the existing structure would appear to be the only alternative in the circumstances. The question may be asked, how did we inherit the present system? An answer would involve a brief assessment of the old colonial policy with regard to its institution known as Indirect Rule. In Uganda, the Agreement of 1900 gave rise to a crop of landlords differing little from their English equivalents, but the tragedy of the situation was that, on such an artificial basis, agricultural landlordism and subinfeudation tended to strangle the growth of Buganda. In Nigeria indirect rule, apart from its two major land ordinances, the Native Lands Acquisition Ordinance and the Land and Native Rights Ordinance, left land matters largely in the hands of local authorities, mostly chiefs acting as sole native authorities, with a consequent *laisser faire* atmosphere which, as was abundantly clear from the confusion in the courts (remedied by a last minute effort transferring jurisdiction in land matters to the Executive) was almost as unsatisfactory a measure as the Buganda pact was a dangerous step. Between these two extremes would appear to lie the solution to many land problems and agricultural problems in Nigeria—what may amount to a reversion, by statutory action if need be, of land seisin not to chief, ordinary citizen, local or native authority or government, but to the community or ethnic group at large. The test of this resettlement would lie in its appeal to the majority, not the few in each unit. Thus in the Northern Provinces, it is reported that chiefs 'complain' that there has been a general levelling up of rights so that the upper classes have tended to settle down to a basis of proprietary ownership differing little from that of peasants. If this is true, then indirect rule has achieved by its policy of non-intervention in land matters what it should have done by direct control. What is the importance of the chiefs' complaint? That seisin has shifted from them to an abstract legal personality, and that personality is the community. There are several reasons why this development must be confirmed. No chief or ruler in Nigeria has ever had a *de facto* proprietary title to land except insofar as clearly defined parcels of land had been attached to the titles held by them. In parts of Nigeria these are termed 'royal estates'. Yet nothing in such privileged holdings prevents the chief or ruler from his share of the communal land. This position has of course led to some litigation as in the case involving Sule Giwa and others with Alashe, quoted above. Not only is this dual title to land in the chief a source of wasteful litigation, it also tends to prevent improvement of the land in beneficial occupation of individuals subject to certain incidents vested in the chief. Thus in Ijero district of Ekiti Division it is stated that all the palm trees belong to the head chief and he is entitled to portions of the produce thereof. Undoubtedly this tax would tend to prevent the usufructuary occupants of that royal 'estate' (here referring to the palms, not the land) from paying sufficient attention to the palm trees. In some cases such occupants are debarred from planting cash crops, in circumstances that otherwise are ideal for such crops, because

the chief or owners of the land look on cash crops as a means of securing a permanent title to land. As already stated, these incidents often lead to abuse, and Elias in his 'Nigerian Land Law and Custom' states that a chief 'receives tributes for his supervisory oversight and may eject or evict grantees for good and sometimes bad reasons'. Clearly the time is now ripe for a general enclosure movement giving a free hand to any, in lawful and beneficial occupation of land, to develop the land resources to the benefit of himself and the country.

There are two systems of conveyance of real property in force in present-day Nigeria, the English and the traditional. It is easy to see the difficulty that may arise when land conveyed under the English method reverts to its traditional owner. This sounds like the theory of estates in English real property law, whereby a parcel of land can be the subject of ownership to more than one person. Yet in the Nigerian context the situation can be complicated by uncertain rules of inheritance mostly empirical and lax. To attempt a demarcation of legal spheres whereby the English system would apply to the exclusion of the traditional is a thing least to be desired. The solution therefore lies in the general resettlement advocated, and it is difficult to see how legal estates or rights or titles can be distinguished in the absence of enclosures to peg them down.

The Law of Property Act 1922 introduced the assimilation of personal and real property in England. It is clear that the population of Nigeria is sorting itself out into two broad divisions, the town and village dwellers. Naturally, there is a two-way movement of people in such a situation; thus the former village landowner may decide to settle in the town and take up trading or some other pursuit, while his town cousin may wish to return to a village estate, as he often does when a relative occupant dies. It will be a useful thing in the country's development if this horizontal mobility of labour is supported by the removal of those limitations which tend to obstruct the mobility of capital, the prime mover of labour. For as we have seen, the cosmopolitan towns in Nigeria are adopting, for the most part, an individualized form of property ownership; but in the villages, the old restrictions placed on land by the often misunderstood communal ownership and its corollary, trusteeship vested in the traditional rulers, tend to battle against the concept of individualized holdings. It is easy to see the stalemate soon to be reached by having one set of conditions in the towns and another in the villages. To forestall this, it would seem necessary to resettle the land as already suggested.

A THEORY OF AGRICULTURAL ECONOMICS

Just as a general streamlining of property, both in the towns and in the countryside, will tend to promote the efficiency of individual enterprise by the removal of those restrictions which hamper mobility of capital, so a general streamlining of agricultural methods beginning with the introduction of enclosures on individualized holdings will not only place farming on a firm footing but will also make it able to anticipate that streamlining which mechanical industry will require when it comes, for agriculture and industry carry each other, and if industry is to be efficient, then agriculture, the older of the two, must be prepared for the strains that the other will bring. We have

reached a situation in Nigeria when no prospect can be held out of our cash crop industry exceeding appreciably the status it reached in the peak years of 1951–52. The last war and its aftermath brought a wave of prosperity formerly unknown in the country. Yet the emergence of the Marketing Boards emphasized the fact that such prosperity, having regard to the unstable nature of world prices, was very near fictitious. Measures were accordingly devised to enable the farmer to bear the fluctuations which were bound to come. In 1953 the palm produce trade felt a shock to the tune of three million pounds loss by the Marketing Boards. It is plain that the Boards cannot pay out such huge sums for an indefinite period. Therefore it is necessary to examine the economic situation of the country as a whole and see if a revision in general principles, as applied to Nigeria, is imperative. We hold the view that in any given agricultural community in the under-developed tropics, what pays for imports is not the export crops but the surplus, expressed in terms of money, of foodstuffs traded and consumed in the community over the export crops. That is to say, the more food grown and consumed at home, the higher will be the imports. This basic principle is vitally connected with the whole case for enclosures in Nigerian agriculture because we believe that the present feckless methods of farming are wasteful of good land and that enclosures will not only lead to intensification of farming in the areas now under cultivation, but also will compel the opening up of parts not before cultivated. This opinion will receive further treatment in the following sections but, for the moment, we will proceed to prove how more food crops grown at home mean higher imports.

It will be necessary for purposes of this illustration to go to the village level and appreciate the farmer's economy. The majority of farmers in Nigeria adopt a bi-functional system of production, cash and food crops. Such farmers grow food crops as a means of direct subsistence and cash crops for what may be described as a reserve, to be called in whenever a shortage arises in their family budget. They regard cash crops as a reserve because they are more readily marketed than food crops. If, as mostly happens, the value of a farmer's food crops is less than would normally support his family, it becomes necessary for him to call in the reserve of funds accruing from the cash crops to supply the deficiency. What remains of this reserve, throughout the whole country, is an invisible surplus which goes out of the country in the form of export crops. There is also the problem of feeding the big urban populations. These non-food producers draw their supply from that surplus released by all food growers in the country with a consequent reduction in the totality of that surplus. But the fact that no famine of the oriental type has occurred in Nigeria within the last thirty years proves that this surplus exists and has been enough to support non-food producers and yet command manufactured goods from overseas. Full recognition, however, must be given to those exported commodities which do not come within the farmer's activity—tin, timber, and invisible exports such as the services of clerks and the like. The influence of these exports on the surplus of food crops over cash crops cannot be high, since certain foodstuffs such as beer, white salt, tinned meat, and fish, confectionery, and the like, have still to be imported. At the village level these imports may be regarded as luxuries. Therefore the influence of these latter exports is that

of a stabilizer preventing too great a fall in our exportable surplus. We may speculate on the extent to which an intensification of food cropping through enclosures can increase the country's output. Probably the acreage under food crops will rise by a third of its present area, and that of cash crops by a sixth, for it is likely that the greater part of the uncultivated area of Nigeria is better suited to food crops than cash crops, although certain crops such as groundnuts can grow almost anywhere. Meek has suggested that the fall in food prices caused by an expansion of food production will tend to drive out of production the smaller farmers, who depend on food crops only. This is, however, unlikely with the rising population of Nigeria.

PROBLEMS OF ENCLOSURE

Just as the economic and social changes of the Nigerian scene tend to promote an individualization of property among the advanced communities, so the social and economic changes in Tudor England altered the attitude of the English towards property ownership. It was a progression to a new concept of ownership based on contract. Thus the great feudal lords in England, robbed of their main source of wealth by the Black Death, and impelled by the new commercial zeal, began an enclosure movement which eventually became the privilege of almost everybody entitled to enclose. Recent research has proved that enclosure in England was not merely a landlords' movement. The peasantry were allowed to enclose bits of the common land, changing in the process the traditional system of land tenure. It was an evolution from status and custom to contract and law. The old common field system was only suited for a primitive state of society and was bound to disappear with the advance of civilization. It was extremely wasteful; the scattering of the farms all over the open fields led to waste of time and confusion; the pace of the common work was set by the worst farmer; no individual initiative was possible; the crops grown were scanty; much of the land was worn out by constant ploughing without manuring; the livestock of the common pastures were small and constantly afflicted by disease. Hitherto subsistence farming had prevailed, but commercial farming was beginning. In the previous centuries as long as a farmer had enough to eat and drink and clothe himself and his family, he wanted little else; now, more and more, he aims to make money; but the most important development of the enclosure system was the fact that the energetic farmer was no longer prepared to mix with the shiftless and lazy. The spur of hard work goaded many a 'working' class family to the middle classes, a good omen in any country. The analogy for Nigeria is obvious. As many Nigerian farmers as possible (nay all of them) must farm for the market. An element of competition must be introduced into such farming so that, as in the Tudor context, a free hand would be given to individual initiative, and the ability, not evenly distributed among men in agricultural methods, to maintain soil fertility, to forecast risks, and weather the storm if it comes. In the process will emerge a strong independent and original thinking middle class, proud in their own achievements, the counterpoise to the white-collared middle classes in Nigerian towns. An admixture of big farmers with the not so big is a thing to be encouraged in each society, for in the enclosure movement envisaged, the right to enclose must be

supported, if necessary, with the ability to enclose, since the problem of the small farmer in Nigeria is that of the rapidly growing weeds. If he cannot command enough labour to keep down the weeds of a large farm, common-sense teaches him to restrict the area of his activity. Yet those who are capable of hiring the labour necessary for large farms are often prevented from doing so because of the traditional obstacle against large farms set by the system of shifting cultivation.

Here two questions are relevant. Who in Nigeria should enclose? Will there be enough land? It would appear that, in encouraging enclosures, the legislature, having regard to the improved traditional system of land tenure in each ethnic group, will enact rules governing enclosures. In doing this the legislature will consult expert agriculturists so that equity may be tempered with science. Thus a formula for determining the right to enclose may be based on conditions similar to these: (1) Every 'son of the soil' patrilineally, in each locality, has a right to enough land for subsistence. (2) A stranger has no right to enclose what he has not bought under deed and seal genuinely attested. Another formula may be devised to compute the area of land to be enclosed outside that referred to in the preceding formula; thus, evidence will be required of past improvement of land and/or years of productive farming related to income tax figures; evidence of no tendency to agricultural landlordism or subinfeudation; evidence of ability to comply with good husbandry legislation. Difficulty may be expected under the new resettlement in respect of large farmers whose plots may lie scattered, thus removing the chief purpose of enclosure—the aggregation of holdings into suitably compact units under the personal surveillance of the proprietor. Here the very concept of communal ownership may be exploited by the legislature in encouraging exchanges. It is reported by Capt. MacBride that in the Northern Provinces, records over 10 years indicate that subdivisions have been counter-balanced by mergers, so that there has been no serious diminution in the size of holdings, which appear to average three or four acres. That there will be enough land for all entitled to enclose depends on the removal of major problems of communication and water supply. It will be necessary to construct what may be termed enclosure roads. The absence of an adequate road system and the habit of certain Nigerian communities, notably the Yorubas, of living in towns and large villages, rarely in farmsteads, tend to pack the land nearest the main roads with a higher density of population than it could bear, so that the back-blocks are often untouched for years.

Thus we come to the two problems of landlordism and a landless class. Having regard to the suggestions already made, these problems may not after all be as serious as they seem. We may draw attention to the happy Ibo communities that thrive all along the railway line in the Northern Provinces from the region of Agana to within a few miles of Lafia, a distance of about 80 miles. In Yorubaland, Sobos have been accommodated and have willingly subjected themselves to a form of rent known as 'isakole'. These strangers, it would seem, have been favourably received by the indigenous population because their presence means more food grown on the land. Can an accommodation be evolved whereby such strangers will acquire a lawful and beneficial occupation of land and yet keep within the terms of their tenancy?

Clearly this is a question of politics and of land policy in the host areas. Where a stranger has been granted a usufructuary occupancy of land, might it not be useful to enclose such land and keep him rigidly within the limits of the enclosure? A landless class in any country is not a novelty. The question is whether the enclosure movement will increase the existing landless class of Nigeria. It depends upon how one looks on the movement as a whole. It would appear that Tudor enclosures were spontaneous and did not, at first, receive the benefit of centralized control. In modern times when controls are accepted as part of everyday life, it would seem that any new enclosure movements would require some control. Thus a scheme for rural credit may be devised to assist genuinely distressed farmers, who otherwise may flee their holdings. Yet it is arguable that, with an increase in food production throughout the country, there will emerge a carrier trade in foodstuffs which, with the development of enclosure roads and such-like communications, will absorb some of the class that may, rightly or wrongly, be described as landless.

AGRICULTURAL BENEFITS OF ENCLOSURE

We have attempted to show that the worst consequences of the English enclosure movement will not necessarily be repeated in Nigeria. We will now proceed to consider some of the advantages of an enclosure movement in the Nigerian context. The gravest problem of Nigerian agriculture is the decline in soil fertility. While in the extreme north of the country mixed farming has tended to arrest this decline, all that is left of the country will some day suffer from the shifting system of cultivation. Enclosed farms in the tse-tse belt will encourage mixed farming to the extent to which it is possible to employ stall-fed cattle, or other cattle immune to trypanosomiasis. The use of artificial manures will be more economical when clearly defined and closed plots are available. The Nigerian veterinary service is well advised to concentrate on adapting the Southern Shorthorn to stall feeding if open grazing is impossible at present. The question of meat cattle should be left to the extreme north where conditions for rearing them are ideal. As regards the northern cattle ranching, enclosures will keep the vagrant and roaming Fulani under control, or even settle them. There is no ethnic difference between the town Fulani and the cattle Fulani. Thus the best principles of cattle and grassland management require paddocks for rotational grazing. A significant feature of the Nigerian peasant farming is the absence of any form of modern farm management. The essential feature of management is the way in which the farmer is forced to think ahead. Now this rarely happens on Nigerian farms. The physical lay-out of the scattered plots, their irregular shapes, their situation in dense forests affording no suitable prospect from which to appreciate the shape of things, the shifting system of cultivation which makes it impossible to assess accurately the condition of fertility before planting, all combine to give an impression of timelessness to most Nigerian farming.

It must be admitted that the extension service of the Nigerian Department of Agriculture has been somewhat narrow, but how can the department be blamed in the absence of clearly defined farms managed consistently by approved farmers, and when farm sites change hands like coins in the open

market? Thus the function of extension work must be limited to demonstration farms, but how many Nigerians go to these farms to study the techniques used? Mechanization of tropical agriculture has been a subject much discussed by experts. Clearly the difficulty is the absence of suitably large farms for the economic use of tractors and equipment. Attempts have been made to aggregate farmers in certain group schemes with a view to mass ploughing of the individual holdings so consolidated. Some of these schemes have proved disappointing because the peasant in Nigeria will not exert himself to the benefit of the many. He would prefer to reap the fruits of his own labour. Besides, these group schemes have often made one fatal mistake; that of inadequate screening of the participants so that the shiftless and lazy are lumped together with the energetic with the consequence that even the energetic soon lose interest. Clearly the answer to the problem of mechanization in Nigerian agriculture lies in what has already been advocated herein, namely to allow individuals to enclose land according to their ability to command the labour necessary for the work involved.

Certain local authorities in Nigeria have, for years past, attempted a system of land registration. In many cases the attempt has failed. We believe that an enclosure movement which has lasted over twenty years will indicate the lines along which registration of titles may be conducted. Thus, in the first period of ten years all who are entitled to enclose will exercise their right over what traditionally or legally, in the case of purchase under deed, belongs to them. Disputes may be compromised (and many have been, without reference to the courts) or settled in the courts if necessary within the period. At the same time, the legislature would enact a statute of limitation applicable to all the country, so that in the second period of ten years all enclosed land would fall under the rules of the statute. If need be, a form of certificate of occupancy may be issued both to the proprietor owner and the usufructuary occupant. On that basis, registration of titles can be carried out equitably, say after twenty years. The vexing problems of land fragmentation have always made registration a farce in most areas of Nigeria. Enclosures, strongly supported by good husbandry legislation, may indirectly check this tendency according as the movement makes land appear scarce. Thus when land has been enclosed for upwards of thirty years, the population continuing to rise, the total area of the country will become ' smaller ' than under the system of shifting cultivation, so that abundance of land on which to let loose reckless broods of children will no longer be a reality and uncontrolled procreation will disappear among certain farmers who will be forced to swallow their greed or else circumvent their neighbours, who are as eager as themselves to retain their enclosed land. Finally, the things of the spirit must not be overlooked in agricultural matters. All intelligent farmers in advanced countries are sentimentally attached to their land, sharing with it its vicissitudes, nursing it in times of difficulty, so that each farmer can say proudly, ' This land is mine and I made it '. We do not believe that the Nigerian farmer is incapable of such sublimation. Let him focus his mind more closely over a given area suitably enclosed so that by dint of hard work, compelled by the circumstances, he can in a few years time say, ' This land is mine and I made it '.

(*Received June 1953*)

A Note on Artificial Insemination of Cattle in Nigeria

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Artificial insemination was first carried out at the Livestock Improvement Centre, Vom, in August 1949. The semen was taken from White Zebu bulls which had come from the Agricultural Department Farm at Shika, Zaria Province. These bulls were later returned and our own Vom bulls substituted. The inseminations were carried out in heifers specially selected and kept apart from the rest of the herd. A few animals known to be empty were sent down from Shika. All these inseminations using native bulls were carried out as an experiment and the present programme using Friesian semen from the United Kingdom did not begin until 5 April 1952.

The semen which came from the Little Harwood Insemination Centre, Buckinghamshire, England, was sent in a boiling tube inserted in an empty ice bag tied at the top and placed in an ice-packed, wide-mouthed, quart size thermos flask. This in turn was enclosed in a cardboard carton padded with cotton wool and completely sealed. The quality of the semen received was good, and only where there were transit delays was the quality of the semen found to be inferior. In such cases it was frequently found that the ice had melted. Provided local air connections between Kano and Jos were good, semen was received here 24 hours after collection in the United Kingdom. On arrival the semen was tested for density and motility.

The main difficulty encountered during the initial experiment, and in the actual insemination programme carried out during the year, was the detection of oestrus. The cows showed none of the normal external signs of oestrus witnessed in the United Kingdom, and to complicate matters they did not return regularly at the twenty-first day. Reliance for detection had to be placed on observant stockmen and by the use of an apron tied round one of our own bulls, which was then led round the herd. Another method tried was the use of a vasectomized bull and this proved quite successful in detection of heat.

Conception rates for the first year were as follows:

Total cattle inseminated	41
In calf to 1st insemination ...	52 per cent
In calf to 2nd insemination ...	64 per cent
In calf to 3rd insemination ...	66 per cent

To increase conception rates it is proposed to give 500–1500 units of Luteinizing Hormone 12 hours after insemination. The cows are inseminated twice daily, at 7 a.m. and mid-day. Oestrus is so short that at second insemination the animal is often found to be out of oestrus.

The cross-bred calves at birth were heavier than the pure Fulani calves. The female cross-breds appear to have no hump, or at the most a slight change in contour. The males, on the other hand, appear to have a hump, although one calf born recently did not. Particular differences were noticed

in width across the region of the buttocks, the cross-breds being very much broader. To take a typical example of difference in weight, a cross-bred heifer calf born on 7 February 1953 weighed 178 lb. at 12 weeks, whereas a pure Fulani White Zebu calf born on the same day weighed 110 lb.

The object of the insemination programme is not to provide a better class of animal for Fulani stock-owners, but to test out half-breds for closed urban dairy schemes especially as regards milk yield and acclimatization.

(*Received July 1953*)

The use of Pot Tests in Research on the Fertility of Sugar Cane Soils

Paper III: A Pot Experiment on the Loss of Effectiveness of Ammonium Sulphate and Superphosphate

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INTRODUCTION

Considerable loss may follow the application of fertilizers to the soil. For example, heavy leaching of nitrate, produced by the oxidation of adsorbed ammonium-ion, may occur soon after the application of ammonium sulphate. Significant loss of ammonia may also occur by volatilization when this fertilizer is hydrolysed under alkaline conditions and high temperature. Similarly, loss of phosphate may occur by lateral surface wash and by downward transportation of finely-divided superphosphate through cracks and between structure units of the soil, as well as by chemical ' fixation ' of phosphate-ion by certain soil components.

In Trinidad, fertilizers applied to the plant-cane crop late in the wet season may only partly be utilized because of a shortage of soil moisture at that time.

The object of the investigation described below was to determine the extent to which ammonium sulphate and superphosphate are lost by volatilization and by ' fixation ' from soil rendered alkaline by liming and alternately wetted and dried in an attempt to imitate late wet season and early dry season conditions.

EXPERIMENTAL PROCEDURE

Soil used in the Experiments—This was obtained from a freshly-ploughed field at the Government Experiment Station at Centeno, which occupies the central part of the Caroni river basin. The soil-type is called 'Cunupia Clay' and is classified as ' Low Humic Gley '. It covers about 20,000 acres of river alluvial land in Trinidad, or nearly 2 per cent of the total area of the Island. It is nowadays mostly utilized for sugar cane growing. The topsoil (6 in.) is a yellow-brown silty loam to sandy loam. Laboratory data pertaining to the sample used in these experiments are given in *Table 1.*

Table 1. Results of Laboratory Examination of the Experimental Soil

Coarse sand (2–0·2 mm) %	*Fine sand (0·2–0·02mm) %*	*Reaction norm. exch. pH value*	*Total organ. matter %*	*Total nitrogen %*	*C/N ratio*	*Total P_2O_5 p.p.m.*	*Avail. P_2O_5 p.p.m.*	*Avail. (exch.) K_2O p.p.m.*
7	30	5·0 4·1	1·2	0·137	5·6	950	15	78
Silty loam		Highly acid	Low	Medium low	Low	Low	Low	Low

The theoretical lime requirement (Hardy-Lewis method) for reaction pH 6·5 is 2·07 g $CaCO_3$ per kg dry soil, or 37 cwt. per acre-6 in.

Preliminary Tests—In order to determine the approximate fertilizer requirements of the indicator plant (Sudan Grass; *Andropogon sorghum var. sudanense*), a preliminary pot test was carried out, using standard Mitscherlich containers, on unlimed and on limed soil.

The following results were obtained:

(*a*) *Lime*: The lime dressing used was 10 g of precipitated chalk per pot which is well above the lime requirement. This gave a highly significant yield increase of 60 per cent over no-lime treatment and a pronounced positive interaction with nitrogenous fertilizer treatments.

(*b*) *Nitrogen*: A dressing of 1·5 g of ammonium sulphate (0·3 g N) per pot gave a 70 per cent yield increase with unlimed soil; larger dressings proved to be harmful. A dressing of 6·0 g (1·2 g N) gave a further yield increase with limed soil.

(*c*) *Phosphate*: Dressings of 0·4, 0·8 and 1·2 g P_2O_5 per pot added as filtered solutions of ' double ' superphosphate, gave increases of yield of 13, 32 and 47 per cent respectively.

(*d*) *Potash*: A dressing of 2·5 g of potassium sulphate (1·2 g K_2O) gave a highly significant increase of 23 per cent and enhanced the yield increases due to nitrogen.

It was concluded from these preliminary trials that appropriate Mitscherlich pot dressings for the experiment proper would be (*a*) 10 g of calcium carbonate (or 2·5 g per kg dry soil) for the ' low ' lime series, and 40 g for the ' high ' lime series; (*b*) 2·0 g of ammonium sulphate (0·4 g N); (*c*) 0·8 g P_2O_5 (as ' double ' superphosphate) and (*d*) 2·4 g of potassium sulphate (1·2 g K_2O) as a basal treatment for each culture.

Details of the Main Experiment—The total weight of soil used in the main experiment was 96 kg (211 lb.). It was passed through a 2 mm sieve, thoroughly mixed and divided into halves. One half was limed ' low ' and the other was limed ' high ' as defined in the last paragraph. Each part was moistened slowly with 12 litres of distilled water and worked up into a loose aggregate structure. Both were then set aside for three weeks with the occasional addition of water to maintain a constant moisture content, and to allow the lime to interact with the acid soil. The soil was then dried out and remixed.

The final reaction of the ' low ' limed soil was pH 6·6 and of the ' high ' limed soil, pH 7·5.

Each part was next subdivided into four portions for the fertilizer treatments. The portions each weighing 12 kg were spread out on a metal tray in a layer 3 in. thick. The fertilizer combinations were four in number, as follows: (*i*) 'Fresh' nitrogen with 'fresh' phosphate, (*ii*) 'aged' nitrogen with ' fresh ' phosphate, (*iii*) ' fresh ' nitrogen with ' aged ' phosphate and (*iv*) ' aged ' nitrogen with ' aged ' phosphate.

The ' ageing ' treatments comprised adding the appropriate fertilizer mixture at the *beginning* of a four months period prior to the time of sowing of the indicator plant. The ' fresh ' treatments comprised fertilizer application at the *end* of the four months period, and immediately before the sowing. During ' ageing ', the soils were moistened on the trays with 1,500 cm^3 of

distilled water in which the correct amounts of ammonium sulphate and superphosphate had been dissolved. The trays were then placed in the greenhouse and allowed to dry out for a week, then mixed, levelled, and remoistened with 1,500 cm^3 of distilled water, allowed to dry out for another week, remixed, remoistened, and so on over the period of four months. At the end of this period all the ' fresh ' treatments were carried out in exactly the same way as for ' ageing '.

Each portion of ' prepared ' soil was finally dried for two days, reground, and passed through a 2 mm sieve and divided into three portions each of 4 kg weight. A small representative sample of each batch was obtained for the determination of reaction and nutrient status.

The 4 kg portions of soil were each moistened slowly with 800 cm^3 of distilled water in which had been dissolved 2·4 g of potassium sulphate fertilizer. The soil was worked up into loose aggregates and finally packed into Mitscherlich pots.

The analytical data pertaining to the prepared soils are presented in *Tables 2, 3* and *4*.

Table 2. Soil Reaction at Various Times after Liming (pH values)

	Low lime					*High lime*				
	1	3	5	7	*Mean*	2	4	6	8	
Three weeks after	—	—	—	—	6·6	—	—	—	—	7·5
Four months later .. .. (Test plant sown)	6·3	6·6	6·7	6·4	6·5	7·5	7·7	7·6	7·5	7·6
Seven weeks later .. .. (Test plant reaped)	6·1	6·1	6·1	6·1	6·1	7·2	7·3	7·3	7·2	7·3

Table 3. Total Nitrogen Content of Soil at Time of Sowing of Indicator Plant (percentage of weight of dry soil)

	Fresh nitrogen		*Aged nitrogen*	
	Low lime	*High lime*	*Low lime*	*High lime*
Fresh phosphate	0·158	0·152	0·158	0·144
Aged phosphate	0·156	0·150	0·158	0·147
Mean	0·157	0·151	0·158	0·145

Table 4. Available Phosphate Content (Truog Value) of Soil at Time of Sowing (parts per million of dry soil)

	Fresh phosphate		*Aged phosphate*	
	Low lime	*High lime*	*Low lime*	*High lime*
Fresh nitrogen	68	80	54	68
Aged nitrogen	64	78	52	68
Mean	66	79	53	68

The pots were sown each with 30 seeds of the indicator plant (Sudan Grass), reduced to 25 seedlings per pot two weeks after sowing. The pots were put in a greenhouse having a glass roof and open sides protected by mosquito netting. They were arranged in three blocks, each containing a randomized set of the eight treatments, four limed ' low ' and four limed ' high '. The position of each pot was frequently changed at random to regulate exposure to light.

The crops were reaped seven weeks after sowing by cutting off the grass stems at their base. They were weighed fresh. The yield data are given in *Table 5*, and the results of statistical analysis are given in *Tables 6* and *7*.

Table 5. Yield Data for Pot-Cultures (grams fresh weight)

	1	2	3	4	5	6	7	8	
Phosphate	*Fresh*				*Aged*				*Block totals*
Nitrogen	*Fresh*		*Aged*		*Fresh*		*Aged*		
Lime	*Low*	*High*	*Low*	*High*	*Low*	*High*	*Low*	*High*	
Block I ..	277	233	237	140	257	229	231	150	1754
Block II ..	271	238	230	150	238	190	227	161	1705
Block III ..	247	228	250	151	283	199	225	168	1751
Totals	795	699	717	441	778	618	683	479	2516

Table 6. Analysis of Variance of Yield Data

	Degrees of freedom	*Variance*	F (*observed*)	F (*calculated*) P=0·05	F (*calculated*) P=0·01
Totals	23	1777	—		
Blocks	2	95	—		
Nitrogen	1	13538	58·8^{xx}	4·54	8·68
Phosphate	1	368	n.s.		
Lime	1	22571	98·0^{xx}	4·54	8·68
N × P	1	433	n.s.		
N × L	1	2090	9·1^{xx}	4·54	8·68
P × L	1	3	n.s.		
Error	15	230·3	—		

Significant difference for treatment totals: 158^{x} 222^{xx}
Significant difference for single values: 112 157

Table 7. Three-way Table for Yield Data (grams fresh weight)

	Fresh nitrogen			*Aged nitrogen*			*Grand total*		
	Fresh phos.	*Aged phos.*	*Total*	*Fresh phos.*	*Aged phos.*	*Total*		*Fresh phos.*	*Aged phos.*
' Low ' lime	795	778	1573	717	683	1400	2973	1512	1461
' High ' lime	699	618	1317	441	479	920	2237	1140	1097
Totals ..	1494	1396	2890	1158	1162	2320	5210	2652	2558

The crop from each culture was then air-dried, pulverized in a hammer mill. subsampled, and dried in the oven at 105°C. The final dry matter samples were analysed for total nitrogen and total phosphate. The results are given in *Tables 8* and *9*.

Table 8. Total Nitrogen Content of Indicator Plant (percentage of oven-dry matter)

	Fresh nitrogen		*Aged nitrogen*	
	Low lime	*High lime*	*Low lime*	*High lime*
Fresh phosphate	1·16	1·31	1·19	0·82
Aged phosphate	1·18	1·69	1·24	1·00
Mean	1·17	1·50	1·22	0·91

Table 9. Total Phosphate Content of Indicator Plant (percentage of oven-dry matter)

	Fresh phosphate		*Aged phosphate*	
	Low lime	*High lime*	*Low lime*	*High lime*
Fresh nitrogen	0·38	0·44	0·40	0·50
Aged nitrogen	0·49	0·44	0·51	0·52
Mean	0·44	0·44	0·46	0·51

CONCLUSIONS FROM EXPERIMENTAL DATA

Yields (Tables 5, 6 and 7)

(1) The 'ageing' treatment significantly depressed the yield obtained with nitrogenous fertilizer by about 20 per cent of the yield given by the 'fresh' treatment. This implies that the added ammonium sulphate suffered considerable loss during the period of exposure to alternate drying and wetting.

(2) The 'high' lime treatment showed a highly significant interaction with nitrogenous fertilizer, which implies that excessive liming caused the greatest loss of nitrogen, presumably in the form of ammonia gas.

(3) The 'fresh' and the 'aged' treatments involving phosphate fertilizer did not show any significant differences in crop response, so that it may be concluded that whatever degree of phosphate 'fixation' took place during the four months 'ageing', it was insufficient to produce any effect on the availability of phosphate to the test plant.

(4) The 'high' lime treatment exerted a significant depressing effect on yield, of the order of about 25 per cent of the control, which however cannot be attributed to diminished phosphate availability, since the variance value for the lime-phosphate interaction is extremely low.

Effects on Soil Fertility (Tables 2, 3 and 4)

(1) *Reaction*: The effect of the four months drying-and-wetting 'ageing' process on pH value was negligible. During the seven weeks growing period of the indicator plant, the pH value of the soil fell considerably, however, both in the 'low' and in the 'high' lime cultures, possibly owing to cation-uptake by the plant.

(2) *Soil Nitrogen*: The total nitrogen contents of the soils three weeks after liming were found to be 0·146 and 0·149 per cent for the ' low ' and the ' high ' treatments, mean 0·1475 per cent. With the addition of 0·40 g N per 4 kg air-dry soil (*i.e.* 100 p.p.m. N), the mean value should have been increased to 0·1575 per cent, and this indeed was the case for all the ' low ' lime additions, both for ' fresh ' and for ' aged ' nitrogen treatments, the mean nitrogen content 0·1575 per cent (*Table 6*) indicating no loss of nitrogen whatever in the ' low ' limed soil during the four months period. In the case of the ' high ' lime treatment, a considerable loss of nitrogen occurred as is shown by the relatively low values (0·151 per cent) for total nitrogen in the ' fresh ' nitrogen treatment, and by the still lower values (0·145 per cent) in the ' aged ' treatment.

(3) *Soil Phosphate*: The ' available ' phosphate content of the original soil, as measured by the Truog method (N/500 sulphuric acid extraction), was 15 p.p.m. P_2O_5, so that the addition of 0·8 g P_2O_5 to 4 kg of dry soil should have raised the value to 215 p.p.m., assuming no fixation. Reference to *Table 4* which gives Truog values at the end of the four months period, reveals the following facts:

(*i*) A large early ' fixation ' of phosphate, as indicated by the relatively low Truog values throughout, which averaged only 66 p.p.m. The fixation was evidently enhanced by the ' ageing ' treatment which gave lower values (mean 60 p.p.m.) than the ' fresh ' treatment (mean 72 p.p.m.).

(*ii*) A considerable reduction in ' fixation ' by ' high ' liming, as indicated by the larger Truog values for ' high ' as compared with those for ' low ' liming (mean 73 v. 59 p.p.m.).

It may be noticed that these differences in phosphate fixation are not reflected by the yields of Sudan Grass in the different cultures.

Effects on Plant Composition (*Tables 8 and 9*)

(1) *Total Nitrogen*: In other previous pot culture experiments with Sudan Grass grown under ideal physical conditions and optimum amounts of NPK fertilizers, the nitrogen content on dry matter was found to be 2·20 per cent. With no nitrogen added, the content was 0·75 per cent; with 75 p.p.m. added, it was 1·20 per cent, and with 150 p.p.m. added, it was 1·80 per cent.

(*i*) Comparison with these values of the data given in *Table 8* shows that the nitrogen contents for the ' high ' lime ' aged ' nitrogen treatment was very low (0·91 per cent), though still greater than the value previously given by no nitrogen (0·75 per cent).

(*ii*) The relatively poor yields given by the ' high ' lime treatments were accompanied by relatively high nitrogen contents of dry matter (mean 1·50 per cent) in the ' fresh ' nitrogen treatments, but by low nitrogen contents in the ' aged ' treatment, because of loss of nitrogen by volatilization.

(*iii*) The ' aged ' phosphate treatment gave consistently higher nitrogen contents than the ' fresh ' treatment (mean 1·28 v. 1·12). A satisfactory simple explanation of this result cannot be offered.

(2) *Total Phosphate*: In previous experiments, the phosphate content of dry matter for optimal conditions was found to be 0·45 per cent, but, when

certain disturbing factors operated, for instance, low soil nitrogen and excessive amounts of lime, the phosphate content increased to as high as 0·54 per cent, and was accompanied by diminished yields.

(*i*) This trend may clearly be traced in the present data (*Table 9*), but the phosphate values have no significance in relation to soil phosphate, because of the interference with phosphate uptake by adverse nitrogen and lime status in this experiment. Nevertheless, the average value for phosphate content of dry matter for the 'aged' treatment was appreciably higher than that for the 'fresh' treatment which implies that 'ageing' did not diminish the availability of the added phosphate.

GENERAL DISCUSSION

The following facts have been established by this investigation:

(1) Appreciable amounts of nitrogen may be lost by volatilization of ammonia from ammonium sulphate added as fertilizer to the top 3 in. layer of a soil whose reaction is neutral or alkaline, or is made so by liming.

(2) The higher the pH value of the soil, the more rapid and complete is the loss of ammonia.

(3) The exposure of soil to conditions simulating those of a dry season in Trinidad for a period of four months duration fails to lower appreciably the availability of phosphate added in water-soluble form to slightly acid soil or to soil whose reaction has been made alkaline by liming.

(4) Hence, the early addition of superphosphate fertilizer to such soils at any time prior to the onset of the wet season may be undertaken without fear of loss of effectiveness.

SUMMARY

1. An acid silty loam (Cunupia Clay), used for sugar cane growing in Trinidad, was shown by chemical analyses and by pot tests with Sudan Grass (*Andropogon sorghum*, var. *sudanense*) as indicator plant to be deficient in nitrogen and available phosphate and to respond markedly to ammonium sulphate and superphosphate fertilizers added in sufficient quantities to supply up to 250 p.p.m. of nitrogen (N) and 300 p.p.m. of phosphate (P_2O_5) to the soil.

2. A factorial pot experiment is described in which the yield responses were measured of that indicator plant to these two fertilizers, supplying 100 p.p.m. N and 200 p.p.m. P_2O_5 to the soil after it had been limed to two different levels.

3. In order to simulate the 'ageing' effect of early application of the fertilizers, whereby nitrogen may be lost through volatilization of ammonia liberated by decomposition of ammonium sulphate, and phosphate may be rendered unavailable by chemical fixation by various soil components, the fertilizers were added to the limed soil four months before the seeds of the test plant were sown, the manured soil being alternately wetted and dried throughout that period.

4. The yield data were statistically analysed and the following results obtained:

(*i*) A large loss of nitrogen occurred, accentuated by high liming.

(*ii*) Available phosphate was maintained at a suitable physiological level during the four months period, even though the chemical availability, as measured by the Truog test, was reduced.

5. Results of soil analyses gave the following additional information:

(*i*) Liming raised the reaction of the soil to pH 6·5 (low liming) and pH 7·6 (high liming).

(*ii*) Nearly all the nitrogen added as ammonium sulphate was lost in the high lime treatment though very little was lost in the low lime treatment.

(*iii*) The chemical phosphate availability (Truog value) of the treated soil was diminished through continued ' fixation ', though to a lesser degree in the high lime as compared with the low lime treatment.

6. Results of plant analysis reflected the yield effects caused by nitrogen-loss suffered by the lime treatment. Phosphate uptake was greater from cultures that had been ' aged ' by repeated drying and wetting than from ' fresh ' cultures.

(*Received November 1953*)

REFERENCES

LEHR, J. J. (1950). ' Differences in the Recovery of Nitrogen from Ammoniacal and Nitrate Sources in the Reclaimed Polders of the Zuyderzee ', *Plant and Soil*, ***11***, 345–358

MARTIN, J. P. and CHAPMAN, H. D. (1951). ' Volatilisation of Ammonia from Surface-Fertilised Soils ', *Soil Sci.*, ***71***, 25 34

SCHREVEN, D. A. VAN (1950). ' Loss of Nitrogen from NH_4-Containing Fertilizers Applied to Calcareous Soils of Zuiderzee Polder ', *Trans. Fourth Internat. Congr. Soil Sci.*, ***1***, 259–261

TOVBORG-JENSEN, S. and KJAER, B. (1950). ' Nitrogen Losses through NH_4 Volatilization after Fertilizing with Ammonium Sulphate ', *Z. Pfl. Ernähr. Düng.*, ***50***, 95, pp 25–38

Book Reviews

PROCESSING MACHINERY

Equipment for the Processing of Rice, F.A.O., Rome, 1953. 55 *pp.*
Equipment for the Processing of Long Vegetable Fibres, F.A.O., Rome, 1953

To those who do not read forewords, two recent publications of F.A.O. will leave a lot to be desired. Expert knowledge of processing machinery is apt to be extremely specialized. Factory control, along with the relatively uniform conditions under which stationary plant is required to operate, leaves little to chance, and tends to remove such equipment from the sphere of the general agricultural engineer. F.A.O. now provides us with a general picture of the equipment for processing (*a*) the most important of tropical food crops, and (*b*) a valuable tropical export. These reviews will give the student and the newcomer a useful introduction to the scope of the processes involved; but the specialist will probably not be edified. The names and details of individual proprietary machines, which are described in the text, are available on application to F.A.O., Rome, Italy.—J.E.M.

ZEBU CATTLE OF INDIA AND PAKISTAN

By N. R. Joshi and A. W. Phillips. F.A.O. Agric. Study, No. 19, 1953. 256 *pp.* 12*s.* 6*d.*

The Food and Agricultural Organization of the United Nations has in the past few years published several review monographs which are extremely useful the world over. However, their value is all the more enhanced in the tropics since good reference libraries are extremely rare and as a consequence tropical workers must depend to a far greater extent upon review material.

This reference work, by qualified animal geneticists, represents an intelligent presentation of the limited information available concerning the breeds of *Bos indicus* cattle which originate within the environs of India and Pakistan. As is too often the case in the field of tropical animal husbandry, this work is not written by a veterinarian. Veterinarians though expert in their own field are usually not qualified to discuss animal genetics or nutrition in any great detail.

Over the past decade there have been three reviews of note dealing with the classification of Zebu cattle in India (Olver 1938, Ware 1942 and Phillips 1944). This work, which is the first entire volume devoted to the subject, brings together this material and also incorporates what little recent reliable literature there is available.

The basic classification of Olver as improved by Ware and Phillips is concisely presented along with excellent pictorial matter and brief data concerning the location, topography, soils, climate, vegetation and management practices of the native environment of each breed. The variation of these features from place to place emphasizes the great differences that exist in the possible adaptability of the various breeds of Indian cattle discussed.

In the past when discussing the environment of tropical cattle a great deal of emphasis has been placed on the climate. Important though this factor may be, it should not completely overshadow the other environmental factors such as those listed above. For the economic production of milk and beef in the tropics the available plane of nutrition of a given area is extremely important and for the first time in discussing the adaptability of Indian breeds of cattle this factor and several others have been considered together with the relevant climatic data.

This publication would be much improved by the addition of a map of India and Pakistan which indicated the geographical location of the localities discussed. Another defect in what otherwise is a highly prized work of reference, is the flimsy cover. It is a pity that all the publications in the F.A.O. agricultural series to date should be so lightly covered, since as reference works they are likely to be much used. Most people are favourably disposed towards paying a little more for a more durable article.—J. R. H.

REFERENCES

Olver, A. (1938). 'A brief survey of the important breeds of cattle in India.' *Misc. Bull. imp. Coun. agric. Res., India, No. 17*
Phillips, A. W. (1944). 'The cattle of India.' *J. Hered.*, **35**, 273–288
Ware, F. (1942). 'The cattle of India and their development.' *Ind. J. vet. Sci.*, **12**, 62–72

THE IMPROVEMENT OF CATTLE IN BRITISH COLONIAL TERRITORIES IN AFRICA

Colonial Advisory Council of Agriculture, Animal Health, and Forestry, Publication No. 3. H.M. Stationery Office, 1953. 144 *pp.* 10*s* 6*d*

This is the report of a Mission consisting of Messrs. D. E. Faulkner and J. D. Brown, a well-known veterinarian and agronomist respectively, of the Colonial Service in Africa. The subject of their survey has been so poorly documented hitherto that this appraisal of the position today will be extremely welcome to all concerned with it. There will be few who cannot learn much from the facts and figures here presented. How many people realize that, as is shown in Appendix III, Zanzibar has the highest cattle population per square mile of any of the territories, or that Kenya has more African-owned cattle than Nigeria with its vastly greater human population?

The report is in four parts—general background, methods adopted by governments for cattle improvement, principles of cattle improvement in tropical Africa, and problems of the individual territories. The first part includes both ecological and social considerations, and gives climographs drawn in the manner popularized by Dr. Norman Wright for this sort of work. The effect of increasing control over diseases in making Africans more interested in livestock improvement is well stressed. In Part 3, the important point is made that in comparing indigenous with European breeds ' the African types are far more productive than is generally imagined ', and this is backed up by figures from Northern and Southern Rhodesia and Kenya. The very thorough reporting, from scattered publications, of experiments carried out in the different territories is one of the most useful features of the report. Part 4 brings out the usefulness of the Livestock Improvement Areas or similar schemes started in a number of the territories in recent years.

It is a pity that this, like so many similar official reports, loses in value because its field of survey covered only the British colonial territories. These territories already have at least some means of exchanging information and being aware of each other's policies. They are often much more ignorant of what goes on elsewhere in Africa. An example in the case of livestock is that the merits of the northern Sudanese cattle with their good conformation and startlingly high milk yields for the African tropics, are almost unknown in the colonial territories though they might well be of use in the more arid environments.

It is important to remember that this report, as is stated in the foreword, is that of a Survey Mission which was not asked to make recommendations as to policy; for it is in considering policy that the report makes the most depressing reading, with its inevitable revelation of discontinuous, inconsistent, and uncoordinated work in the past. The presentation of so much useful information should, however, make this less likely to recur in the future.—G.B.M.

A GARDENING NOTE-BOOK FOR THE TROPICS

A. V. and V. L. Gibberd. Longmans Green & Co., 1953. 184 *pp.* 6*s*

This is not a note-book in the sense of Wood's ' Note-Book of Tropical Agriculture ' but a continuous text, albeit divided into paragraphs by concise sub-headings. The authors have drawn deeply on their practical experience in Nigeria, but express a hope in the preface that the book will be found useful in other parts of the tropics, and to assist this object have included a chapter comparing different tropical climates. The chapters on the principles of tropical gardening are certainly of general application, but in those dealing with individual flowers and vegetables the authors have perhaps not fully realized either the possibilities or the difficulties of gardening in some other tropical environments—particularly the dry tropics and the high altitude regions. Within the West African region the book will be of special value, and another hope expressed in the preface that through it many Nigerians may be induced to take up gardening and enjoy its pleasures may be echoed with sympathy.—G.B.M.

COCOA

Cultivation, Processing, Analysis

EILEEN M. CHATT. Interscience Publishers Inc. New York & London, 1953. 302 *pp.* (illus.) $8.50

The appearance of a new book on Cocoa must be welcome, for no comprehensive account of the crop has appeared since the 2nd Edition of van Hall's ' Cocoa ' more than 20 years ago.

This book is an ambitious one as its sub-title—Cultivation, Processing, Analysis—indicates, and aims to cover the entire field from the growing of the crop to its final processing for the consumer. In this lies its weakness for it is almost inevitable that one aspect is dealt with at second hand, in this case the field and cultivation end.

After chapters on the history and botany of the crop comes one dealing with cultivation. Vegetative propagation is treated very sketchily and rehabilitation is not mentioned. To quote VAN HALL (1914) on suitable fertilizers for tropical agriculture is not very helpful. To say that the reason for introducing shade is that it protects the humus layer of the soil against drying out through exposure to the intense rays of the tropical sun is so gross a simplification as to be misleading. Nor can an earlier statement that the degree of photosynthetic activity depends on the concentration of stomata on the leaf surface be accepted. On p. 30 the net assimilation rate is given as 0·9 gm. per sq. dm. per week. This is a misprint for 0·09.

The sections on processing and analysis are very full and well supported by references. Indeed the main value of the earlier chapters on field aspects lies in their documentation. They would be of little practical use to the grower of the crop, whose interest in the book would of necessity lie in the description of what happens to his crop after he has shipped it from his estate.—D.B.M.

LEGUMES IN AGRICULTURE

R. O. WHYTE, G. NILSSON-LEISSNER and H. C. TRUMBLE. F.A.O. Agric. Study No. 21, 1953. 367 *pp.* (illus.) 15*s*

Over one hundred contributors have assisted the authors of this publication to produce an up-to-date factual survey of the role of legumes in farming in both temperate and tropical countries.

The book is divided into two main parts; the first deals with the economic botany of legumes and the role that legumes can and do play in farming systems in relation to soil fertility, in pasture mixtures and in alternate husbandry. The second part of the publication is concerned mainly with a description of leguminous genera and species of importance to the farmer, the stockman and the soil conservationist.

To the worker in the tropics the information collated in chapter seven is of particular interest in that, from information obtained from a wide range of countries, there are given details of the various legumes which are of actual or potential value and which are commonly grown or which are under trial in the tropics and in the sub-tropics, the subject matter in this chapter being on a geographical basis.

The publication brings together in an acceptable and readable form an abundance of useful information regarding the part which legumes can and should take in all branches of farming. It draws attention too, to the scanty information which exists in the tropical field. Those concerned with tropical agricultural development will find much that is stimulating and much that is useful in this publication which is up to date in its information and which has spread its net over a wide field.—A.B.K.

RICE

D. H. GRIST. Longmans Green & Co., 1953. 331 *pp.* (illus.). 35*s*

A note in the introduction to this book states that it is one of a series of volumes to be published, with the active encouragement of the Colonial Advisory Council of Agriculture, Animal Health & Forestry, under the editorship of Sir Harold Tempany, C.M.G., C.B.E. In fact this volume dealing with the Rice Crop is the first of the series. The author D. H. Grist is to be congratulated on the production of a work which is not only timely in appearance but which covers in a comprehensive manner all aspects of rice production in the main rice-growing areas of the world. The early chapters of the book deal with the botany of the plant and its overall cultural requirements, the important pests and diseases of the crop are dealt with fully and in a practical manner; the later chapters deal at length and on a world

basis with all aspects of the cultivation of irrigated and dry-land paddy, while the closing sections of the book are concerned with milling and storage problems and the nutritional value of the crop.

In the section on mechanized cultivation the writer surveys the extent of rice mechanization in various parts of the world and clearly demonstrates the contrast between Asiatic and American developments. He makes the point that a fundamental difference in principles exists between the Asiatic conception of increased tillering by wide transplanting and the American demand for reduced tillering by close planting using broadcast seed, a difference which is fundamental in its effect upon mechanization. A very useful summary of the results of mechanization trials, mainly in Malaya and British Guiana, is also included.

As an up-to-date practical treatise on this the most important crop in the world this volume should be in the possession of all who are concerned with rice production. If subsequent volumes in this series maintain the high standard set by this first publication, the series will form a most valuable addition to the literature of tropical crop agronomy.

The volume contains an extensive bibliography and is illustrated by seventy-two photographs.—A.B.K.

The Indigenous Breeds of Sheep in Africa and their Improvement

J. P. Maule
Director, Commonwealth Bureau of Animal Breeding and Genetics, Edinburgh

Including the Karakul population of south-west Africa, there are about seventy million indigenous or cross-bred types of sheep in Africa. In addition, there are some twenty million Merino sheep in South Africa, and small numbers of Merino and other non-indigenous wooled breeds in Kenya, Southern Rhodesia and North Africa.

There is very little information on the indigenous breeds and on their improvement in tropical Africa. By far the most detailed accounts of the improvement of mutton qualities of indigenous sheep are those reported from Tanganyika from 10–15 years ago. In the following notes, I propose to describe some of the typical breeds of sheep and to summarize the various attempts which have been or are being made to improve them, particularly in regard to mutton production.

Given below are approximate figures for the numbers in the main territories (excluding wooled sheep in South Africa)

		Million sheep	
East and Central Africa:	Ethiopia	10·0	
	Sudan	5·0	
	Uganda	1·0	
	Kenya	3·0	
	Tanganyika	6·5	
	Nyasaland and N. Rhodesia	0·1	
	Belgian Congo	0·1	
		—	25·7
West Africa:	French West Africa ...	10·0	
	Nigeria	2·0	
	Gold Coast and Sierra Leone	0·5	
		—	12·5
South Africa:	S. Rhodesia	0·1	
	Basutoland	1·5	
	Bechuanaland	0·9	
	South Africa (non-wooled and Karakul)	6·5	
		—	9·0
North Africa:	Morocco, Algeria, Tunisia, Egypt (approx.) ...	20·0	
		—	20·0
	Total ...		67·2 million

Very few sheep are found in the equatorial humid tropics (*e.g.*, the Congo and coastal belts), the largest concentration being in dry, savannah-type country (*e.g.*, Tanganyika, Northern Nigeria, the Sudan and South Africa). Large numbers are also found all along the North African coast and, perhaps surprisingly, in Ethiopia.

In comparison, there are approximately seventy million sheep in the Indo-Pakistan sub-continent and about twenty-five million in the rest of the tropics, but there are no indigenous sheep in South America and the West Indies.

TYPES OF SHEEP

Most of the indigenous African types or ' breeds ' are hairy coated, there being very few coarse-wooled sheep, other than those in North Africa. BETTINI (1941) has described five main types of African sheep as follows:

(1) Ancient Egyptian or Hamitic, from which has been evolved the hairy, hornless, long thin tailed Sudanese.

(2) Fat tailed wooled sheep of North Africa, including Egyptian and Barbary types.

(3) Fat tailed, brown-coloured sheep, *e.g.*, Masai, and common Ethiopian type—variable skin, generally poor quality.

(4) Blackheaded Somali sheep, from which the Blackhead Persian was evolved. Berbera Blackhead has the best skin quality.

(5) Long fat tailed Afrikaner sheep of South Africa (also Shoa and Tanganyika long tailed type).

This ' classification ' does not seem to include other well-defined types, such as the Nilotic sheep (between 10°–12° long.), small, smooth coated, white or patchy with small horns; the West African dwarf or Fouta Djallon type, and the West African Macina, thin tailed, wooled type.

In the ' World Dictionary of Breeds, Types and Varieties of Livestock ' (1951), MASON defines the following indigenous types:

(1) *Wooled sheep*
- (*a*) Thin tailed (Morocco and Algeria)
- (*b*) Fat tailed, Barbary (Tunisia and Libya)
- (*c*) Macina, large, long thin tail, white fleece (French Sudan)

(2) *Non-wooled or Hairy sheep*
- (*i*) *African long legged*, long thin tail
  - (*a*) Sudanese and Zaghawa (desert and upland types)
  - (*b*) Congo and Baluba
  - (*c*) West African (Maure, Tuareg and Fulani types)
- (*ii*) *East African fat tailed* (short tail)
  - Abyssinian
  - Masai
  - Madagascar
- (*iii*) *Long fat tailed*
  - Afrikaner—Namaqua and Ronderib varieties
  - Shoa
  - Tanganyika long tailed (Ugogo)

(*iv*) *Fat rumped*

Somali and Blackhead Persian

(*v*) *Dwarf*

West African—Fouta Djallon

The Nilotic sheep of the Sudan should also be included under dwarf types (though Mason did not do so); adult rams often weigh no more than 25 lb. Of the non-wooled types, only those found in Tanganyika, South Africa and French West Africa have been described in any detail.

Distribution

It will be seen from the map shown below that the main types tend to fall naturally into different geographical zones. Thus the wooled sheep occur only in the northern belt, and in one area in West Africa where there are about one million Macina sheep (Mason, 1951). The comparatively large African long-legged sheep extends across the widest part of the continent from French Guinea to Abyssinia. The fat tailed and fat rumped types extend all down the eastern region from Abyssinia to the Cape. Dwarf sheep are found in the humid, wetter regions of equatorial Sudan and the Niger coast.

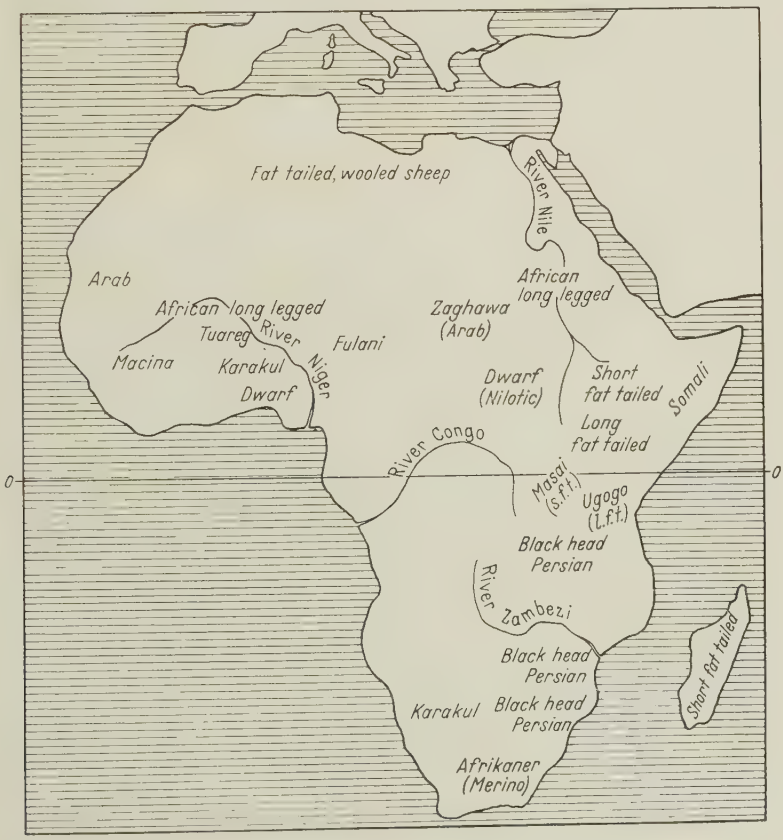

Figure 1. Distribution of sheep breeds in Africa

One type has not been included, namely, the Karakul. This is not indigenous to Africa but was introduced in the last century to south-west Africa. It appears to be increasing in numbers, probably as a result of the good market for pelts and its ability to thrive in a hot, dry climate.

DESCRIPTION OF MAIN TYPES

The African Long-legged Sheep

This type is best represented by the Desert or Arab sheep in the Sudan and by the Tuareg and Fulani sheep in West Africa. The characteristic feature of both varieties is their size (70–80 cm in height) their long, thin, tapering tail and short hairy coat. No information seems to be available on such points as lambing percentage, carcass weight or growth rate.

The desert sheep of the Sudan is a particularly large, brown and parti-coloured sheep, adult males weighing up to 150 lb., and is considered by far the best sheep in the Sudan. Ewes of this breed are good milkers and will give as much as 5–6 lb. daily. These sheep inhabit the drier northern upland areas where they are kept by nomadic Arabs; they do not thrive in the riverain areas (BENNETT *et al*, 1948).

The West African long-legged sheep includes several sub-types, the Arab, Tuareg and Fulani, but all are large sheep, with long pendulous ears, and varying in colour from white, spotted or fawn to a pied variety in French Niger. Rams are usually horned and ewes polled. They are good mutton sheep and are also fairly good milkers. Fulani sheep have excellent mutton qualities.

They inhabit the whole of the northern part of West Africa, from Mauretania on the west (Arab or Maure) to Chad in the east, and they are found both within the Niger bend (Tuareg) and along the northern region of Nigeria (Fulani).

There is also a long haired, black variety of Arab sheep in the French Sudan which resembles the Zaghawa found in Darfur, in the Anglo-Egyptian Sudan. The French variety has recently been crossed with Karakul rams.

East African Fat Tailed Sheep

This type is best represented by the ' Masai ' which is found principally in Kenya and Tanganyika where it is kept by the nomadic Masai tribe. It is a large, long-legged sheep with a short hairy coat, usually reddish or brown (the breed is sometimes called the ' Red ' Masai), but white-and-brown and all-white sheep are found. Some sheep have a woolly under-coat. The distinguishing feature is probably the short fat tail. Sometimes the tail appears to have been cut off level with the buttocks and in this case the tail fat may be carried on the rump.

Mature wethers will weigh up to 110 lb. liveweight; they are quicker growing than other types in Tanganyika and give a lean carcass.

Long Fat Tailed Sheep

This type is found in limited numbers in Abyssinia, East Africa and South Africa, but it varies in size and conformation in different regions. French has described the Tanganyika sheep which is called ' Ugogo ' as being a

Figure 2. African long-legged, long thin tail, type (Sudan)

Figure 3. East African fat tailed type; a Masai ram (Photo. by D. E. Faulkner)

small, stoutly built, many-coloured sheep with well-sprung ribs, good loin and a fatty dewlap. They may be white bodied, with black, white or yellow heads, or they may be piebald or roan. The tail is full of fat but varies considerably in shape and size. Fat wethers will weigh 80 lb. upwards. They grow slowly, weighing about 40–45 lb. at one year, and are not mature until four years old. If well fed much higher liveweights can be obtained.

STARKE (1952) has given an account of the origin and distribution of the Afrikaner sheep of South Africa. These are descendants of the original Hottentot sheep which, according to Epstein, probably originated in north-east Africa and migrated southwards. Today there are approximately 1·3 million Afrikaner sheep represented by two main types, the Namaqua and the Ronderib, but they are steadily decreasing in numbers, being replaced by Karakuls.

The Namaqua is considered to be of a purer type than the Ronderib. In general appearance it is a fairly large sheep with short, narrow body and long legs, and is creamy white in colour with a short fleece and undercoat which protects it from the cold. It produces a lean carcass with a fat deposit in the tail. Rams weigh 110–140 lb., ewes 70–100 lb. The Ronderib is rather larger than the Namaqua and gives a slightly better carcass. Lambs are not normally marketed until about 12 months old but in good seasons they may be ready at eight months. A heavy carcass of 48–50 lb. is obtained when they are nearly full grown.

Because of their adaptation to the environment, Afrikaner sheep have been of considerable importance in the drier, less favourable areas of the Cape. A certain amount of crossing has taken place between the two Afrikaner types, and with Blackhead Persian and Karakul, so that there are few pure bred Namaqua sheep left. In areas suited to non-wooled sheep the Dorper is now competing with the Ronderib Afrikaner for mutton production, since the former will produce a marketable lamb at 6–8 months and also because of the difficulty that rams of other breeds have in serving Ronderib ewes (ANONYMOUS, 1952).

Various other types of Afrikaner sheep have recently been described (*Farmers' Weekly*, 1950). The Bezuidenhout Afrikaner is a wooled type said to have been developed from the Blackhead Persian. Another type is the Van Rooy White Persian evolved from the Ronderib Afrikaner by crossing with Rambouillet and Blackhead Persian rams. They are said to give a 100 lb. lamb at 7–8 months off the veld (MORISON, 1949).

The Blackhead Persian

The Blackhead Persian has been bred in South Africa since about 1868; it is similar to the unimproved black-headed Somali sheep found in Somaliland and Kenya and now numbers about two million head.

It is a fat rumped, non-wooled sheep whose characteristic black head and neck and white body give it a distinctive appearance. Its main qualities are its hardiness in the dry areas, and its prolificacy and ability to breed all the year round. It does not, however, produce a good mutton carcass and is therefore used largely in South Africa for crossing either with rams of British mutton breeds or with Karakul rams. In Tanganyika, Blackhead Persian rams have been used on the indigenous Masai and Ugogo sheep in

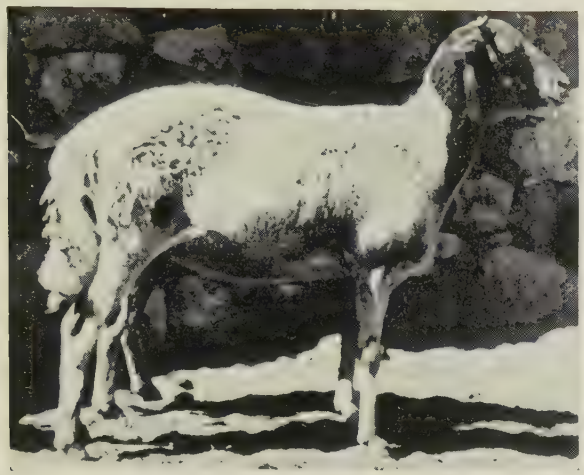

Figure 4. Long fat tailed type; a Namaqua ewe (Photo. by permission of Prof. F. N. Bonsma)

Figure 5. Fat rumped type; Blackhead Persian (Photo. by D. E. Faulkner)

order to improve growth rate and carcass weights. This work will be referred to below.

The practice of crossing Persian ewes with Karakul rams has increased considerably of late, so much so that pure-bred Persian stock have decreased in numbers. When crossed with rams of mutton breeds Persian ewes give a useful cross-bred lamb which grows quickly; under favourable conditions these are marketable as fat lambs. Blackhead Persian sheep have also been used a good deal for cross-breeding in Southern Rhodesia with Dorset Horn and Wiltshire Horn rams, but neither cross has been outstanding though the cross-breds do make better growth rate than pure-bred Persians.

The Blackhead Persian is now tending to be replaced in South Africa by the 'Dorper'—a breed developed from the Dorset Horn × Persian half-bred. This is a non-wooled, white sheep with black patches on the face, and with better body conformation and fat distribution, and quicker growth rate than the Persian. Lambs are said to reach a slaughter weight of 70 lb. in 4½–6 months, and to give a much better carcass (MEYER, 1951).

Dorper sheep are also being tried in Rhodesia and Nyasaland and it seems probable that, as more breeding stock become available and the breed improves, it will be used increasingly in these and other areas.

USE OF WOOL BREEDS IN THE TROPICS

Where the environmental conditions in the tropics are reasonably good and Europeans have settled (*e.g.*, Kenya, Abyssinia, Rhodesia), attempts have usually been made to develop wooled sheep by crossing with breeds such as Romney Marsh and Merino.

Thus in Abyssinia during the Italian régime emphasis was on wool production to augment Italian domestic supplies, but no extensive cross breeding to 'grade up' the hairy local sheep to wool breeds appears to have been attempted (REINBOTH, 1939). It seems probable that very little was achieved during this period, although an extensive reserve was put aside for studying the various local types and for building up flocks of Apulian Merinos imported from Italy. Experimental crossing of the latter with Somali type sheep was said to have proved satisfactory but this work may have lapsed during the war of 1939–45. In the Kenya Highlands, both Merino and Romney Marsh sheep have been successfully introduced. Bisschop described the Merinos as being 'rather small and refined both in body build and in their fleece'. Various attempts to introduce wooled sheep to Tanganyika have been made and they appear to have been uniformly unsuccessful, mainly on account of the heavy parasitic infestation which causes high mortality. Thus trials with Romney Marsh and Merinos in 1932 failed and in 1943–44 Black Welsh Mountain rams were introduced in an attempt to improve the mutton quality of the local sheep, but these crosses did not survive.

In Madagascar attempts have been made, since 1921, to improve the fat tailed sheep by crossing them with Provençal, Châtillonais and Dishley Merino rams, but of these only the Provençal cross has been a success. The Provençal sheep referred to may be the Arles Merino or one of the triple-purpose breeds found in southern France (RANSOM, 1950).

Most of the work undertaken until recently in French West Africa was directed towards improvement of the quantity and quality of wool in the Macina breed by crossing with Merino rams (LALANNE, 1948). Different types of Merinos were tried, the Arles Merino proving the best. It was found that the wool was considerably improved in the higher grades but that sheep with more than 75 per cent Merino blood were unable to survive and after 40 years' work these experiments have finally been given up (DOUTRESSOULLE, 1952).

Recently some Cheviot sheep were imported to the Bamenda plateau of the eastern region of Nigeria, presumably for crossing with the local sheep.

None of these attempts seems likely to be of permanent value since wooled sheep are not adapted to a tropical environment.

Karakul Sheep

This breed is not indigenous to Africa but it is of increasing importance, particularly in south-west Africa, and also in other countries where it has been introduced for crossing with local sheep with the intention of building up a trade in pelts.

In South Africa there are now over 1½ million Karakul sheep and numbers continue to increase. They thrive in the dry areas where mutton sheep do not, and it has been shown that pure-bred Karakul and their crosses with Blackhead Persian make good liveweight gains and will give a satisfactory carcass (BADENHORST and HEINICHEN, 1953).

Crossing with Karakuls

West Africa—The introduction of Karakuls to French West Africa dates from about 1929 when a number were imported to the French Sudan, but in a few years this work seems to have been expanded. The black Maure breed is said to have proved satisfactory for crossing; the cross-bred giving a fairly good pelt, though this is not yet an economic proposition (DOUTRESSOULLE, 1952). Work is also in progress in the Niger Colony and at Chad. Macina, Fulani, Tuareg and black Chad ewes have been crossed with Karakul rams at Filinqué. The coat of the half-breds resembled that of the Karakul but the tails were thin like those of the native breeds (TANNIÈRE and BOUCHÉ).

There are now over 200 pure-bred Karakuls in the Chad region and over 1,000 cross-breds some of which have been distributed for breeding (CREPIN).

No such work has yet been attempted in Nigeria or other British colonies.

East Africa—Karakul sheep have been used for several years in Tanganyika for up-grading a mixed flock of local sheep. The results obtained in the higher grades appear to have been very variable and the pelts from 7/8th grades were not of high quality. (FRENCH, private communication, 1952). The main Karakul flock has deteriorated very much since 1950, but the cause of this is obscure. Karakul sheep were also introduced to Abyssinia but there seems to be no record of the outcome of this experiment.

IMPROVEMENT OF INDIGENOUS BREEDS FOR MUTTON

Experiments in Tanganyika

French carried out a series of experiments on the growth rates, development and carcass quality of Tanganyika sheep and various crosses, in particular with the Blackhead Persian.

He compared the growth rate of the local fat tailed Ugogo and Masai with a number of crosses. Liveweights obtained at birth, six and twelve months in 1938 and 1939 were as follows :

Table 1

	Liveweight (lb.)			
	Birth	6 *months*	12 *months*	18 *months*
(1) Ugogo	4·7	26·3	42·1	54·7–62
(2) Masai	6·6	38·4	59·4	76·3
(3) Ugogo × Masai	5·0	31·0	39·0 (10 mths.)	
(4) Blackhead Persian × Ugogo	5·6	26·7	—	
(5) Blackhead Persian × Masai	5·1	28·7	38·9 (10 mths.)	
(6) 3/4 Blackhead Persian/Ugogo	5·8	32·3	40·4	55·6–69
(7) Blackhead Persian × Welsh Mountain	7·1	31·5	—	
(8) Masai × Welsh Mountain ...	7·2	31·25	—	

From this it is clear that the Masai are the quickest growing and they reached a liveweight of 76 lb. at 18 months. The introduction of the Blackhead Persian produced a lamb intermediate between the two local types in liveweight and slightly earlier maturing, but it did not produce a lamb of better quality. This aspect of the original cross breeding work may, however, have been due partly to the quality of the Blackhead Persian stock used. Further work is in progress using the improved South African type of Blackhead Persian.

The use of Black Welsh Mountain sheep was tried because they were similar in size and rate of growth, and produced good quality, small mutton carcasses. It was hoped that they might stand up to the conditions and give progeny likely to adapt themselves. The failure of the cross-bred lambs to maintain growth rate was partly attributed to the fact that their Persian dams had insufficient milk. Mortality of the Welsh crosses was also heavy.

French also compared the mutton qualities of the two local breeds with the 3/4 Persian × Ugogo cross. His results have been given in a series of papers (French, 1938*a* and *b*, 1942, 1944). French's conclusions as a result of some 10 years work were as follows :

(1) Masai sheep have poor skeletal development, but heavier and longer bones than the long tailed sheep. The quality of the mutton is poor. Crossing with Blackhead Persian did not improve mutton capabilities as judged by skeletal development, although the cross-breds can be killed at an earlier age; this cross has a higher proportion of fat.

(2) The 3/4 Persian is slightly heavier and earlier maturing than the Tanganyika long tailed sheep, but it has a poorer fat distribution, and the introduction of Persian blood has not had any influence on the proportion of valuable joints or on carcass quality.

(3) Crossing the local breeds with imported fat tailed breeds will not improve mutton quality. Crossing with Blackhead Persian increases the proportion of fat in the carcass and adult cross-bred sheep yield poorer carcasses than local sheep, but the cross-breds are usually earlier maturing.

(4) There is little difference in mutton quality between the local types; crosses between them did not improve either quality or proportion of lean to fat.

(5) The best method to improve mutton quality is by crossing with a European breed. The success of this depends on improving the environment sufficiently for grade sheep to thrive, and finding the amount of European blood compatible with this environment.

Other Experimental Work

Apart from the work carried out in Tanganyika and that of crossing Blackhead Persian ewes with mutton rams in South Africa and Southern Rhodesia, very little has been attempted to improve the carcass quality and yield of local breeds.

This is no doubt partly due to the inability of the imported mutton breeds to thrive—or even exist—in most parts of the tropics, and partly to the unsuitability of the climate and conditions for cross-bred stock.

In Southern Rhodesia, various crosses have been tried using the Blackhead Persian as the foundation. At present Dorset Horn and Wiltshire Horn rams seem to offer the best chance of producing a satisfactory cross-bred mutton sheep. In South Africa a Southdown × Blackhead Persian cross gave a quick growing lamb but the lambing rate was low (Meyer, 1950).

An attempt to improve the mutton quality of one of the Egyptian breeds, the Ausimi, a fat tailed, wooled breed, has been reported. In this case a Suffolk ram was used, the cross-bred lambs weighing 94 lb. at 24 weeks *v.* 67 lb. for the Ausimi. In body conformation and carcass quality the crosses resembled the Suffolk (Sidky, 1948).

In conclusion it appears that little success in improving the indigenous non-wooled sheep by cross breeding is likely to be achieved in the tropics, mainly on account of the susceptibility of the cross-bred stock to disease, and of their non-adaptation to the environment. Possibly the Dorper or some similar type may prove the most likely sheep for the better areas, or in districts where there is European management. For the African there seems little opportunity for improving the mutton quality of existing sheep breeds except by raising the nutritional level.

(*Received December 1953*)

REFERENCES

Anonymous. *The indigenous sheep of Hottentot origin in South Africa.* Unpublished MS

Badenhorst, D. F. and Heinichen, W. (1953). 'Mutton-production capacity of Karakul sheep.' *Fmg in S. Afr.*, **28,** 76, 106; *Anim. Breed. Abstr.*, **21,** No. 1292

Bennett, S. C. J., John, E. R. and Hewison, J. W. (1948). 'Animal Husbandry.' *Agriculture in the Sudan*, Chap. XXII, pp. 633–642. Oxford University Press, London

Bettini, T. M. (1941). 'Sull'origine degli ovini africani. *Riv. Biol. colon.*, **4,** 215–236; *Anim. Breed. Abstr.*, **14,** No. 230

Bisschop, (J.) H. R. (1949). 'The improvement of livestock in Kenya.' Broadcast talks and report on his visit to Kenya, March 1948. Nairobi. *Anim. Breed. Abstr.*, **18,** No. 1

BRESSOU, C. and MORNET, R. (1949). 'Le mouton Astrakan en Mauritanie.' *C.R. Acad. Agric. Fr.*, **35,** 398–403; *Anim. Breed. Abstr.*, **19,** No. 184

CAMPBELL, Q. P. (1952). 'The last stand of the Blackhead Persian.' *Fmg in S. Afr.*, **27,** 487

CREPIN, P. (1952). 'Le troupeau Astrakan du Tchad.' *Mouton*, **7,** 31–32; *Anim. Breed. Abstr.*, **20,** No. 1111

DOUTRESSOULLE, G. (1952). *L'élevage au Soudan français. Son économie.* Algiers. 2nd ed. *Anim. Breed. Abstr.*, **21,** No. 1021

'Hardy sheep for sparse veld. Bezuidenhout Africanders developed and improved under exacting conditions.' *Fmrs' Wkly* (*Bloemfontein*), **78,** 1950, 55; *Anim. Breed. Abstr.*, **18,** No. 585

FITT, R. H. and MORRISON, A. A. (1947). 'Sheep and their management in Southern Rhodesia.' *Rhod. agric. J.*, **44,** 280–289; Reprinted in *Bull. Dep. Agric. S. Rhod.*, No. 1403; *Anim. Breed. Abstr.*, **16,** No. 543

FRENCH, M. H. (1939). 'The mutton capabilities of Tanganyika sheep.' *Ann. Rep. Dep. vet. Sci., Anim. Husb. Tanganyika Territory*, 1938, Pt. II, 62–70; *Anim. Breed. Abstr.*, **9,** No. 222

— (1938*a*). 'Development of livestock in Tanganyika Territory. II. Tanganyika breeds of sheep, and mutton qualities of the long-tailed type and its crosses with Black-headed Persian sheep.' *Emp. J. exp. Agric.*, **6,** 112–124; *Anim. Breed Abstr.*, **6,** No. 109

— (1938*b*). 'Development of livestock in Tanganyika Territory. III. Skeletal measurements of local fat-tailed and grade Black-headed Persian sheep.' *Emp. J. exp. Agric.*, **6,** 246–252; *Anim. Breed. Abstr.*, **7,** No. 315

— (1942). 'The growth-rates of local and cross-bred sheep.' *E. Afr. agric. J.*, **8,** 24–25. (Adapted from *Rep. Dep. vet. Sci. Tanganyika*, 1939, Pt. II); *Anim. Breed. Abstr.*, **11,** Nos. 30–31

— (1944). 'Development of livestock in Tanganyika Territory. VI. The development of mutton qualities in Masai and grade Black-headed Persian sheep.' *Emp. J. exp. Agric.*, **12,** 207–218; *Anim. Breed. Abstr.*, **13,** No. 29

LABUSCHAGNE, F. J. (1948). 'The Blackhead Persian.' *Fmg in S. Afr.*, **23,** 77–83, 106; *Anim. Breed. Abstr.*, **16,** No. 1010

LALANNE, A. (1948). 'Le mouton à laine et le croisement Merinos-Macina au Soudan français.' *Bull. Serv. Élev. Industr. anim. Afr. occid. franç.*, N.S., **1** (4), 5–13; *Anim. Breed. Abstr.*, **17,** No. 912

MASON, I. L. (1951). *The Classification of West African Livestock.* Commonwealth Agricultural Bureaux, Slough, Bucks

— (1951). *A World Dictionary of Breeds, Types and Varieties of Livestock.* Commonwealth Agricultural Bureaux, Slough, Bucks

MEYER, W. D. (1950). 'Progress in development of mutton breeds.' *Fmrs' Wkly* (*Bloemfontein*), **79,** 51

— (1951). 'The Dorper: its characteristics and value.' *Fmg in S. Afr.*, **26,** 289–290; *Anim. Breed. Abstr.*, **20,** No. 210

MORISON, J. G. (1949). 'South African breeds of sheep.' *Fmrs' Wkly* (*Bloemfontein*), **76,** 55, 57; *Anim. Breed. Abstr.*, **17,** No. 1349

RAATH, J. C. (1949). Report of Animal Husbandry Officer for year ended 31st December 1948. *Rhod. Agric. J.*, **46,** No. 4, 1949, p. 243

RANSOM, E. T. (1950). 'The Karakul industry of South-West Africa.' *Foreign Agric.*, **14,** 183–186; *Anim. Breed. Abstr.*, **18,** No. 1433

REINBOTH, G. (1939). 'Wollschafe in Abessinien.' *Z. Schafz.*, **28,** 102–103; *Anim. Breed. Abstr.*, **8,** No. 47

— (1940). 'Die äthiopi(s)che Schafzucht. *Z. Schafz.*, **29,** 39–40; *Anim. Breed. Abstr.*, **9,** No. 121

L'élevage du mouton à Madagascar. *Rev. Élev.*, **4,** 1950, 204–208; *Anim. Breed. Abstr.*, **20,** No. 717

SIDKY, A. R. (1948). 'The Egyptian sheep: an attempt to improve quality and quantity.' *Emp. J. exp. Agric.*, **16,** 79–89; *Anim. Breed. Abstr.*, **16,** No. 1012

STARKE, J. S. (1952). 'Development of the non wooled sheep.' *Fmg in S. Afr.*, **27,** 87–91

TANNIÈRE, G. and BOUCHÉ, P. (1950). 'Essai d'acclimatation de moutons karakuls au Niger. Résultats obtenus dans le croisement continu karakuls × indigénes.' *Bull. Serv. Élev. Industr. anim. Afr. occid. franç.*, **3** (1), 23–39; *Anim. Breed. Abstr.*, **19,** No. 694

Hafirs or Development by Surface Water Supplies in the Anglo-Egyptian Sudan

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THE OUTLINE OF THE PROBLEM

About one-third of the area of the Anglo-Egyptian Sudan—or some 300,000 square miles, just over three times the size of the British Isles—withholds its potential of pastoral and agricultural wealth for the primary reason of shortage of drinking water. Roughly two-fifths of this area are predominantly sandy country suited for cattle; two-fifths are clay plain suited for rain-dependent agriculture; and one-fifth clay plain suited for rain-dependent agriculture only if the severe flooding from storm water during the rainy season can be controlled. The rain dependence of agriculture in these plains is contrasted with the irrigation-dependent agriculture that at present forms the backbone of the Sudan's economy, but which takes place outside and to the north of the areas under consideration. Irrigated agriculture is limited in potential expansion to a maximum of 16,000 square miles, even if all the water ever likely to be allotted to the Sudan from the Victoria Nile is harnessed, plus the water at present wasted in the swamps taking the drainage of the north-eastern slopes of the Nile–Congo watershed.

Were the 300,000 square miles unbroken plain, little development by surface water supply would be possible because the rainwater would be absorbed where it fell; but the plain is broken at wide intervals in the east and centre by inselbergs and in the west by weathered sand dunes. Exploitable water catchments are formed by the inselbergs and their plinths and by the clay–sand mixtures formed round the sand dunes by the washing out of their clay fraction by rainwater. Natural catchments give rise to scanty water supplies that support some permanent and many seasonal settlements over the large areas lacking underground aquifers.

The nomadic outlook sees the earth's resources as illimitable. This has resulted in heavy unplanned pressure upon natural water supplies, and as a result each is the focus of an area of exhausted soil and, where slopes are steep enough, of actual erosion. To cure this condition by planned pastoral and agricultural works is one aim in the development of surface water supplies. This is now vitally important because the rapid national development is unbalanced in disfavour of the land and the demand for rural products will outstrip a supply which depends upon what Sir Philip Mitchell has called an 'African and his hoe' economy. This weak economy must be bolstered to meet expanding demands until the new techniques of rational pastoralism and mechanized agriculture—which alone can grasp the opportunities offered by such vast areas—have been perfected, otherwise this weakness might be the source of an economic collapse, leading perhaps to a political one, in which all that has been gained since Sir Herbert

Kitchener's time might be lost. It is believed that much can be wrung from the old peasant economy by the elimination of the distances between the field and the water point.

Existing water supplies allow the use of three per cent or less of the agricultural land and the pastoral land to be used at a low efficiency. Until just after the second world war practically the entire effort to improve water supplies was devoted to tapping underground sources, but for reasons of non-water-bearing rocks and shortage of geophysical survey equipment, this yielded meagre results. No large-scale effort to exploit surface storage methods was possible, because the heavy earth-moving equipment needed was only developed in America just before the war started. Towards the end of the war there arose a determination among those responsible for the welfare of the Sudan to attempt the development of the rainlands, partly for their own sake and partly to broaden the basis of the country's economy by farming which did not have cotton as its mainstay. Cotton had always been the main revenue producer and the fear—perhaps less than was justified—that it would one day be supplanted by something else and leave the coffers empty, inspired the venture into the rainlands, a venture which is still not proven but lies in the realms of promise.

EARLY WORK

The noun ' Hafir ' is the Arabic word for a hole in the ground excavated for the storage of rainwater. Hand dug hafirs have been used in the clay plains of the Sudan probably from time immemorial and their outlines are visible over a wide area, the denuded banks still holding shallow pools after heavy storms. Hafirs are the obvious means of water storage in areas of impervious clay without underground aquifers. It seems that the majority of the old hafirs were dug in an era of greater rainfall when the flooding of the land by rainstorms was a regular occurrence, for they consist simply of horseshoe shaped excavations with open mouths and no special arrangement to obtain water from torrents or rock catchments.

In 1946 six Caterpillar D7 tractors and six Le Torneau 11 cubic yard scrapers to match, were procured by the then Department of Agriculture, through the para-military organization the Middle East Supply Corporation, for the purpose of mechanical hafir excavation. Though they had not been tried for this specific purpose Dr. J. Smith, then Deputy Director of Agriculture, was convinced that they would work. The machines were based upon workshops at Wad el Huri near Gedaref, started a few years earlier for other lines of rainland development, which were expanded to deal with servicing problems.

The purchase of the machinery was the expression of the desire to produce surface water supplies on a large scale, but at that time staff and experience were limited. It was soon realized, after a successful trial, that the output of such a collection of machinery would necessitate the services of a body of civil engineers with supporting junior staff, both for preparatory work several years in advance of its field operations and currently for essential completion works. Several years passed before this need was fully appreciated and recruitment started. In the meantime excavations were made at a number of sites obviously suitable for hafirs both from social and hydrological

angles, which enabled the machinery to be used to advantage without too serious mistakes being made. The need for a full establishment of qualified staff became urgent as the machines moved to new country where no existing information was available about hydrological conditions and the nature of soils, and where social problems arose involving new settlement and changes in the grazing routine of nomads. By now the staff of the Department of Agriculture and of the Forestry Division, who had so generously lent their help in the early days, were fully engaged with post war programmes of their own.

THE PRESENT ORGANIZATION FOR CREATION OF SURFACE WATER SUPPLIES

The present organization of the Soil Conservation and Surface Water Supplies Section was set up to deal with hafir programmes and other works which, since 1949, have meant the disposal annually of some 800,000 cubic metres of excavation in from 50 to 60 hafirs, and the construction of up to 1,500 kilometres of graded earth access roads. The excavating machinery is actually worked by a Mobile Plant Depot, the manager of which is responsible through the Chief Engineer to the Director of the Ministry of Agriculture. The Mobile Plant Depot acts as a contractor for works planned by the Soil Conservation and Surface Water Supplies Section, and before the beginning of each working season, which starts in mid-October and finishes about mid-June, the Soil Conservation Officer passes to the manager of the depot a plan of work, so that the latter may make his dispositions involving rail or river transport and fuel oil supplies.

The Soil Conservation and Surface Water Supplies Section consists of a headquarters unit based in Khartoum, and four regional offices at Kassala, Sennar, Malakal and El Obeid. The headquarters section co-ordinates plans, orders supplies, and maintains an execution team that reinforces the small permanent staff of the regional offices in the seasons when they are visited by machinery. The function of the regional offices—staffed by a civil engineer, a foreman of works and two surveyors—is to carry out permanent reconnaissance and maintenance of works already completed. For maintenance work the regions also have a watchman or two on each hafir and a maintenance foreman for each group of about 20 hafirs.

For hafir excavation the Mobile Plant Depot—now with its workshops just outside Khartoum—uses two fully mobile excavation teams each based upon six Caterpillar D7 tractors with a Carryall 11 cubic yard scraper to match, and two other D7 tractors, one pulling a rooter for loosening the subsoil, and one fitted with a bulldozer blade for clearing sites. In addition each team has adequate road vehicle and tanker transport for fuel oil and water, and sufficient repair equipment to keep the team working long distances from its base for seven months each year. Shelter for crews is provided by tents; the mechanical engineer in charge of the team has a caravan.

For access road grading there are two self-contained road teams, one with a capacity of about 12 miles per day of nine-metre-wide graded earth road, and the other with a capacity of about five miles per day.

The output from all machinery, considering the conditions of utmost remoteness, is gratifyingly high, and this must be attributed to the keenness and ability of all staff involved. The excavation teams work a 24-hour day

in three shifts: a long shift from 0700 hours to 1800 hours, followed by another long shift up to 0500 hours, followed by a short shift of two hours by greasers completing the 24 hours. Drivers on the long shifts make their own arrangements for short stops for feeding, which is usually done communally in local tradition. The establishment of staff of both excavation and road teams is now completely Sudanese, and the only European supervision is that of an engineer who tours the four units—sometimes widely dispersed—during their field season, and of the manager of the depot who makes occasional tours during the same period. The workshops and stores at the base have a small European staff.

In addition to seven-and-a-half months of arduous field routine the staff of the excavation teams have to cope with any incidents that occur, from the heavy job of replacing broken tracks and clutches on the tractors and changing steel cables on the Carryalls, to dealing with attacks by wild bees. On one occasion whilst clearing an hafir site the bulldozer demolished a tree containing a bees' nest, the occupants of which at once attacked the interloper. The driver fled precipitately. A brave volunteer, covered in sacks, tarpaulins and other sting-proof apparel, returned to turn off the engine of the tractor, but the whole job of digging that hafir had to be done by night, as the bees returned to the attack each dawn and held the field till dusk.

THE SEQUENCE OF FIELD WORK

The plan received at the beginning of each season by the Manager of the Mobile Plant Depot is in the first place the result of the five-year plan agreed to by the Rural Water Supplies and Soil Conservation Board, and in the second place, of a number of years of preparatory work by the Soil Conservation and Surface Water Supplies Section. So far as the latter is concerned, hafir programmes involve the following sequence as a basis for amendment:

First year	...	preliminary reconnaissance
Second year	...	reconnaissance track clearance
Third year	...	clearance of access tracks
Fourth year	...	site investigation and grading of access tracks
Fifth year	...	excavation and completion of hafirs.

This sequence must be regarded as the one that would be followed were there absolutely no knowledge of the country in which hafirs were needed and if there were ample time for preparations. Always there is some knowledge and never is there ample time for preparations, and this means that some of the steps may be omitted or may have to be sandwiched into one year. In extreme cases in the days of early operations barely one season's reconnaissance work was done, but here at least there was a fairly detailed knowledge of the country and a willing staff of helpers from the Ministry of Agriculture and from the Forestry Division.

Preliminary reconnaissance has as its object the determination whether the country proposed is in fact suitable for development by hafir water supplies, that is to say, whether conditions of hydrology and soil are suitable and compatible, and administrative conditions favourable. It may, for instance, be clear that soils over a particular area are too thin for surface storage or too pervious, or the difficulties of access and supply of the weighty

machinery may be too great and expensive. Some areas may have too short a working season owing to late drying out after the rains or the late abatement of annual floods.

Should the preliminary reconnaissance show that an area is generally suitable for hafirs, the existing road system—if there is one—is examined to see what additional tracks may be needed for reconnaissance parties, and the general lines and extent of these decided upon before the next season's work. When the next season, that is year number two, begins, field parties scrape temporary tracks with medium tractors and scrapers and where necessary clear lines through the bush, though clearance is avoided as far as possible until the following season when definite commitments for the future are undertaken. From these tracks a better knowledge of the country is gained, and the main hydrological features and distribution of soil types, so far as they concern hafirs, are charted sufficiently to shape the excavation programme.

Before opening the third working season the lines are chosen for the permanent access roads which will be needed for the passage of the excavating machinery, for the maintenance of the finished hafirs, for the extraction of new produce resultant from the new water supplies and for the inward movement of consumer goods. During the season these lines are cleared to a width usually of 12 metres. The work is preferably done by contract and costs anything from £E.20 to £E.60 per mile. With the contractor's men are road trace foremen from the Soil Conservation and Surface Water Supplies Section who have been trained in setting out such traces for long distances on compass bearing or upon landmarks.

During the fourth season the access traces, previously cleared, are graded by the two road teams, and this costs about £E.16 per mile. While this is going on survey parties are levelling and soil-testing prospective hafir sites. The degree of levelling necessary depends largely upon the way in which the hafir is to be filled.

In general filling sources fall into the following categories, though they are not watertight compartments, and in practice one source may have the characteristics of more than one category: inselberg catchment (close), inselberg catchment (remote), seasonal torrent, swamp, gardud, and artificial catchment.

(i) *Inselberg catchment* (close) is used in the case of small inselbergs which are too small to form torrents with their surface run-off of storm water. Since the Sudan has a large number of inselbergs in its clay plains, and as these are often the only means of concentrating the storm water sufficiently to make it usable, much attention has been given to this form of catchment, particularly in the Blue Nile Province. Basically the method involves putting a canal at a suitable slope just above the line at which the inselberg merges with the cottonsoil plain. An estimated figure of three per cent of the average annual rainfall falling upon the inselberg and its plinth is collected. This is a safe figure and it is usually exceeded. The water from the catchment canal is led away to the hafir site in a lead-in canal, and the site is usually perforce some distance away from the inselberg in order to obtain sufficient depth of soil, which is seldom required to be less than six metres and may be up to ten. A snag in this method is the expense involved in preventing scour in the lead-in

canal which in most cases has to run at a fairly steep slope. If possible, though lack of time and the difficulty of transporting materials often prevent it, this is done by the installation of weirs in masonry or gabions. If this is not possible and scour cannot be avoided a silt trap of about one-tenth the size of the hafir may be interposed before the hafir.

(*ii*) *Inselberg catchment* (remote) is used where an inselberg, or a group of linked inselbergs, is sufficiently large for its run-off to form local torrents. Hafirs may then be sited to fill from these torrents using short intake canals of a 100 metres or so in length and the expense of collection and long lead-in canals is avoided. Sometimes an hafir may be needed some distance out in the plain where there is no annually occurring water source: in this case the tail of a torrent may be extended using a suitable machine to form a canal. Carryalls have been used most successfully for this purpose and in one instance, using a natural depression as a line, a cut of 20 kilometres was made, which now brings more than enough water to fill an hafir of total size exceeding 300,000 cubic metres.

(*iii*) *Seasonal torrents* vary considerably in usefulness as hafir fillers according to their size and characteristics of velocity, silt content, regularity and proximity to impervious soil. The ideal torrent is one which brings clear water at a non-scouring velocity and just enough of it to fill the hafir. The further this ideal is departed from, the greater the expense in completion works to ensure maximum life between major maintenance operations and filling, in a season of small flushes, and to defend the hafir against heavy spates which overflow the normal bed of the torrent. Large torrents often have beds of pervious silt along their banks with the impervious clay retired at awkward higher levels; carefully levelled canals are then necessary as lead-ins and their banks may give trouble through cracking in the dry season. The faster the torrent, the greater the amount of silt and debris carried, and the more likely it is to make local changes of course which may leave the offtake point high and dry or cut off from the hafir from behind. Whatever the nature of the torrent the general rule followed is that in securing an offtake point local hydrology is interfered with as little as possible: offtakes are sited on the outsides of gentle bends so that the mainstream impinges directly on to a radius of the curved downstream pitching of the canal head. This method has been found successful over a period of trial and error in the Gash delta, where some 50,000 acres of cotton and grain growing land are irrigated by floods from the Gash river torrent each year.

Two main classes of torrent are distinguishable with many intermediate examples. At one extreme is the torrent which only flows with one heavy flush for a few hours in the season, and at the other, the torrent which flows with reasonable regularity. With the former a large volume of water has to enter the hafir in a short time and carefully thought out designs have to be made and executed. Where there is ample water the best answer to inlet works is to be found in the use of steel pipes, provided there has been time to get the pipes ordered from supplying countries. Where time is very short and an hafir has to be filled in a very few hours, masonry works of very ample section have been used. These are satisfactory in actual performance but they are expensive to construct and maintain, as building sand, stone and aggregate are usually remote from sites.

Figure 1. Jebel Meleisa, or 'The Smooth Jebel', a small inselberg between the Blue and White Niles

Figure 2. An aerial view of Abu Sana hafir of 25,000 cubic metres capacity

(*iv*) *Swamps*, with their clear water, are the best fillers of hafirs, and small diameter and therefore cheap pipes can be used for inlets. The only downward limitation to the size of pipe is the necessity for it to be large enough to avoid choking with debris and this can be prevented by the use of suitable screens. If filled from swamps, care must be taken not to plan hafirs too near the water's edge, for the site must dry out sufficiently for the machinery to work as soon as it arrives.

A variation of the swamp as a source which is very useful, is the small swamp formed in the S bends of an old bed of a large torrent. These S-bend swamps are well known and have special native names; they act as excellent silt traps and obviate the need to take special precautions in the construction of canal offtake heads.

(*v*) *Gardud* is an Arabic word which means an area of non-cracking clay or clay and sand mixture. It is usually slightly elevated above the surrounding plain and on a slight slope and therefore productive of a run-off of storm water. Two features commonly give rise to garduds: denuded or vestigial inselbergs where a plinth only shows above the ground and small sandhills at whose edges the sand had been washed down and mixed with the clay of the surrounding plain, or whose clay fraction has been washed out and mixed together with some of its own sand to form a non-cracking apron with run-off propensities. Hafirs filled from gardud catchments use the same system of catchment and lead-in canals as those filled from inselberg (close) catchments.

(*vi*) Because of expense and shortage of staff *artificial catchments* have up to now been avoided, with one exception. Various forms of artificial catchment have been considered for use when necessary and they are mostly based upon the use of bitumen in making impermeable a clay area which would not normally have a run-off. But in the one case where an artificial catchment has been made about 750 acres of heavy clay forest land have been drained by a herringbone system of ditches made by a road grader. The slopes in the area do not exceed one in a hundred and there would seldom be free surface water for collection. Observations of run-off from the roadside drains on earth graded roads under comparable conditions showed that about 50 cubic metres of water could be collected per acre drained. It is hoped at least to half fill an 80,000 cubic metre hafir in this way. Preliminary reports, received as this is being written, show that the herringbone drainage system seems to be working better than was expected.

The problem of settling the details of catchments and the collection of water therefrom, goes hand in hand with that of finding suitable soil for the hafir. Here the two most important qualifications are clearly depth and impermeability. Certain surface signs give a good indication of both these attributes: black soil as opposed to red or brown; even cracking as opposed to pot-holing or no cracks; level ground as opposed to sloping; absence of surface pebbles and the absence of trees other than *Acacia mellifera* and *Balanites aegyptiaca* are, taken all together, good indicators of soil depth and impermeability. Sites thus shown to be favourable must be checked by soil sampling, which is done by the tedious but so far irreplaceable method of digging test shafts. To start with three test shafts are dug at the corners of

an equilateral triangle of side length 60 metres, with the centre of the triangle over the centre of the proposed hafir. Should one of the shafts strike unsuitable material it is abandoned and another dug to make another triangle on the opposite side of the other two shafts; this manoeuvring is continued until a satisfactory triangle is found. Should the area as a whole be promising for suitable soil, the triangle of three sound shafts is taken as a sufficient proof of a good site, but in the case of difficult areas further pits must be dug at the corners and centre of the hafir to make sure.

The degree of departure from the ideal of pure impermeable clay that may be tolerated in cases where hafirs are urgently needed in particular sites depends upon the way in which imperfections occur. Impermeable clay mixed evenly with quite a large amount of sandy material will pass, but bands of pure sand in pure clay are difficult to deal with, especially if they are at low levels or through the bottom of the hafir. The only thing which can be done is to cover sand on the bottom with clay brought in by the machines at the time of digging, and to dig away bands of sand in the sides, causing the clay from above to collapse and seal them off.

During the fourth season of preparation the question of the sizes of the future hafirs must be decided. Because the Sudan is still largely a country of nomads, tribal communities and shifting populations - particularly in the areas where hafirs are dug - precise calculations are not possible as to future demands for water. A fair division of the season's work amongst the various claimants in an area is a major factor influencing size; so are the degree of hardship already suffered from shortage of water, the probable speed and extent of resulting development, the most economical size for the excavating machinery and any other local factors.

For *agricultural purposes* hafirs are usually needed for either *permanent settlement* or for *seasonal cultivation only*. In the case of permanent settlements water must also be allowed for domestic animals, and an allowance is made of a minimum of three cubic metres per month per family with domestic animals. This may seem small, but it is generous compared with previous standards. The smallest hafir used for permanent settlement is of 30,000 cubic metres size and the largest about 80,000 cubic metres. These sizes—allowing for half the water being lost by evaporation and some loss of capacity from silting before maintenance—are estimated to support 500 and 1,300 families respectively; to date this capacity is not fully taken up though demand increases each year. The effective offtake period is taken as 300 days per year as during the remaining 65 days loss will be made good from direct catchment of rainfall and reduced by animals drinking from pools. The larger of these two hafirs represents about the maximum size desirable. If an hafir is still bigger it means that cultivators will have to walk too far to their furthest land. A big hafir supporting 1,300 families and that number of cultivators, on a three course bush/bush/cultivation rotation at 10 acres of cultivation, will need 39,000 acres. This area represents a square of side just over eight miles and diagonal just over 11 miles. If the village were in the centre of the square, which cannot always be arranged, a villager might have to walk five-and-a-half miles to his land; if the village were not central distances would of course be greater.

Figure 3. A finished hafir in the Blue Nile Province of about 20,000 cubic metres capacity just after the first water had entered

Figure 4. Typical arrangement of two stop log gates, one for inlet water and the other for surplus water

A note on village land layout is not out of place here. African rainfall and growth conditions are notoriously uncertain and it is necessary to include some provision against the cultivator's misfortune if the rains miss his plot. In the case of higher rainfall areas this is attempted by dividing the village land in long strips rather than squares; in areas of lesser rainfall a chequer board system distributes the season's cultivated land over several squares. Individual plots are not demarcated but allotted according to tribal custom within the blocks.

The allowance of three metres depth of water for evaporation and silting is very generous: in fact, annual evaporation computed from Piché figures varies from just over one metre to just over three metres from an open water surface, but further south, and thus further into comparatively low evaporative conditions, the season of demand for water becomes shorter, and hafirs may therefore be smaller on two counts.

For *seasonal cultivation* not requiring settlements hafirs can naturally be smaller. They do not have to maintain large numbers of animals and demand occurs at a time of year when evaporation is low and losses largely replaced by direct catchment from rainfall. Many successful hafirs have been made for the Dinka tribe, their capacity varying between 6,000 and 10,000 cubic metres. To be fully effective it is important that these hafirs provide water for cultivators who come to prepare their land at the end of the summer, before the new rains make the catchments run. Thus the water must last from the end of one cultivation season throughout the summer for these preparations at the beginning of the next season, and a margin of extra size is necessary to compensate for evaporative loss.

Hafirs in this class are also provided for the utilization of 'harig' land. 'Harig' is a technique—its large-scale use is believed to be unique to the Sudan—whereby accumulations of old grass are used to rid the land of new weeds by burning off old and new together: it is naturally practised only in remote areas where fires started by human beings are not all-pervading. Harig areas are also, of their nature, waterless, and in the past they have been worked by hardy peasants coming long distances by camel and existing on the barest minimum of water, taking great chances that water from puddles will enable them to stay long enough for the establishment of their crops. Often unfavourable rains have resulted in the loss of crops through a shortage of drinking water. Small hand dug hafirs, even at wide intervals, have helped to increase the yield of this form of cultivation, and the bigger mechanically dug ones should ensure this increase.

For *stock* the size of hafirs must be correlated with the nature of the grazing, with existing water points, water potential which can be developed from other sources, the number of animals and the time they are intended to graze the area, and with any other local factors. To assess the importance of these things, study by pasture research officers is required. In the early days of hafir construction such study had not been made, and water for stock was provided by siting hafirs at the most convenient places along migratory routes. Now a more refined approach is made. A major object of schemes for improved grazing is the strengthening of good grass species, and this is planned by dividing the country into strips, one of which is rested each year. With water points few and far between, a great deal of grazing is wasted by

being trampled to pieces and blown away; at the same time much of the energy obtained from the grass is wasted when the animals have to walk long distances between grazing and watering points. These defects are common knowledge, so common that they seem to be accepted by the nomad as an immutable natural law. A difficulty in improving grazing conditions is that stock are managed on a tribal system which, with the best will in the world from tribal leaders (and some are very co-operative), is difficult to rationalize into anything like the ranching plan one would like to see.

In southern Darfur in the extreme western Sudan, a scheme for grazing improvement based upon hafirs is being carried out. So far 15 of a probable total of 45 hafirs have been dug; their average size is about 7,000 cubic metres, varying from an individual 3,000 to an individual 12,000 cubic metres. This scheme, which is incorporated with the seasonal migration of the Rizeigat tribe, falls into two parts. The area concerned is in the centre of the tribe's annual north to south migration route and the northern half of the scheme involves division of the route into three strips watered by hafirs and a few natural shallow well fields. One of the strips will be closed each year to strengthen the grasses therein. In the southern half no strips are provided but the whole is to be protected from the annual total fires by a system of firelines and fire-guards. It is not intended to hold the tribal animals within the area of the scheme for the whole year, but to delay their passage to their summer grazing grounds to the south by about two months, so that the grazing there will be better able to last out the summer. At present it is very severely punished and in poor years many beasts die of starvation. Another reason for the need of more grazing in these parts is that, in common with other areas in the western Sudan, it has for several years been the scene of an intensive anti-rinderpest campaign. This has resulted in a large increase in the number of animals to be fed.

Before leaving the subject of hafirs used for stock mention must be made of a successful and important operation carried out in the 1950–51 and 1951–52 seasons. This consisted of the provision of water by hafirs along 300 miles of a 600 mile route from stock raising country in the south-western Sudan to a new canning factory recently erected by Messrs. Liebig at Kosti on the White Nile. It was intended to have hafirs on the route at 15 mile intervals, which was considered by the veterinary authorities to be the best spacing, but lack of time for reconnaissance resulted in an average interval of about 30 miles. The hafirs are of 25,000 cubic metres capacity each and are dug as twins of equal capacity. The object of this is to facilitate desilting when it becomes necessary, as one half may be pumped into the other when the levels have dropped sufficiently and clearance work carried out without leaving the point waterless. The two halves were dug in successive seasons, and a strong supporting reason for this action at the time was the very high price of cotton grown in the area of Kordofan Province south of the hafirs. This enabled a considerable extra capacity of hafirs to be given immediately to the cotton industry, which has paid quick dividends. In addition to the hafirs along this route it is hoped to make a group near Kosti which will enable cattle to stay in a holding area to act as a reservoir of animals and stabilize the flow to the factory.

In the fifth year of the programme the spotlight is on the Mobile Plant Depot and its staff and machinery in action in the field. Together they are indeed spectacular and the spectacle is matched by the satisfaction of the staff of the Soil Conservation and Surface Water Supply Section in seeing their long-prepared plans come to fruition. This does not imply that the section is now a looker-on. The field staff from headquarters have to follow the excavation machinery as closely as possible, installing finishing works to each hafir. These works, which cost on an average £E.500 per hafir, comprise masonry flumes or piped inlets with suitable offtake arrangements from feeding canals, weirs to prevent scour where necessary, housing for the watchman, housing for the area foreman, fencing and water extraction plant with water points for human beings and animals.

The question of what kind of water extraction apparatus should be provided proves difficult to answer. The object is to extract the water in adequate quantities in such a way as to avoid completely any contamination by infected human beings or animals. The apparatus provided must do this and at the same time be foolproof and capable of maintenance by the very simplest-brained persons. After much thought a solution has been reached in an outside well connected to the hafir by an underground pipe. The well is fitted with a diaphragm pump—thus avoiding metal valves—and has a sealed cover. If the pump breaks down irreparably the well cover may be removed and dippers used temporarily. The principal snag to this otherwise good solution is the difficulty of installing the underground pipe, which must be laid at a depth of about six metres. For this purpose a thrust boring machine has been bought and is under test, though at present the pipes are laid down in a hand excavated trench—a very tedious thing to dig as it is about 100 feet in length besides being deep.

The principal waterborne disease to be guarded against in the Sudan is bilharzia. So far no hafirs have been shown to carry this infection, but the strictest precautions are taken. (Hand pumps are used on hafirs up to about 20,000 cubic metres and mechanical pumps on larger hafirs. An advantage of the outside well system is that the well itself has some significant capacity and several pumps may be grouped upon it or one mechanical pump substituted for several hand ones.) In addition to the water-extracting apparatus fencing is considered important: this again gave much food for thought before a standard form was decided upon. Five strand barbed wire fences are now installed. They are rather expensive, but attempts to avoid this expense by using local materials for poles and thorn filling failed through the depredations of termites, fire, and the laziness of watchmen.

COSTS

Because of the shortage of accountants no attempt has yet been made to find out individual costs for each hafir. All that can be achieved is a figure compounded of all the various costs of the processes described, divided by the number of hafirs or cubic metres produced. Upon this basis, over a total of 276 hafirs of total capacity with feeder canals of about three million cubic metres of excavation, the cost per cubic metre has worked out at just about seven shillings. This cost comprises the following:

	s.
Hire charges on excavation machinery ...	3
Clearing and grading access roads	1
Completion works	1
Establishment charges	2
Total	7s.

The establishment charges refer to the cost of regional and headquarters offices and therefore include reconnaissance work.

Actual costs of individual hafirs may vary greatly from the average figure of seven shillings per cubic metre: probably they would be as low as five shillings or as high as 10 shillings. The figure for hire charges on excavation machinery includes the fees paid for rail and river transport which run into £E.3,000 to £E.4,000 a year with both teams, and it includes all idle running time between sites, during which each team covers between 1,000 and 1,500 kilometres a season.

The above remarks apply to capital costs. In planning hafir schemes for the future account must also be taken of day to day running costs. Each hafir costs about £E.200 a year to maintain: about half of this sum is taken by the watchman's wages, about one-quarter by a repair contingent which may be spent not annually but when necessary as a greater sum, and about one-quarter by an annual contribution to access road maintenance of which the major part is the removal of grass after the rains and the filling in of pot-holes. Access roads must be regraded about every five years, though in favourable circumstances the interval may be longer. In a handier form these figures of capital and maintenance costs work out at two shillings per cubic metre of water to the consumer, assuming a depreciation of the hafir in 20 years. In practice water is not generally charged for because of the opportunities for peculation in the collection of many small sums in divers remote places.

It is the policy of the Sudan Government to hand over all hafirs as they are constructed to local governments for day to day running and maintenance. This is not easy as in some places local governments have not yet emerged, and where they have emerged their resources of skilled supervisors are too small to meet this demand. It is considered best, however, to press on with the handing over, so that local authorities may learn by seeing their own mistakes.

As a result of hafir operations during the last six years some nine million acres have been put within reach of the cultivator, to be exploited by his ancient methods. Before the full resources of the rainlands can be released much remains to be done to develop practical new agricultural methods suited to African conditions: meanwhile by the provision of simple surface water supplies the ' African and his hoe ' economy may be enabled to carry on, supporting the demand of development in other fields until this release is achieved.

(*Received October 1953*)

The Work of Agricultural Demonstrators in Southern Rhodesia

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In 1927 the first 11 agricultural demonstrators were appointed in the Department of Native Agriculture, Southern Rhodesia. Six years later community demonstrators started work and in 1937 soil conservation demonstrators were appointed. Forestry demonstrators came along in 1940 and livestock demonstrators four years later. In 1947 (20 years after the first 11 appointments) there were 361 African supervisors and demonstrators.

At present there are over 500 demonstrators stationed in the native areas of Southern Rhodesia. More than 400 of these are engaged on agricultural demonstration, and the remainder on soil conservation work, community development, livestock work and forestry.

In all matters affecting agricultural demonstration and development these demonstrators come under the Land Development Officer, but matters affecting pay and discipline are referred to the District Commissioner. Ideally, a Land Development Officer has an area of some 250,000 acres under his charge. The African staff for this area consists of 10 demonstrators and one supervisor. Thus each demonstrator has an area of about 25,000 acres of which 3,000 acres or more may be arable land. The supervisors are recruited from the ranks of the demonstrators and their job is to visit these men regularly, to help with advice and to check on their work. The supervisor acts as the liaison officer between the demonstrator and the Land Development Officer.

The demonstrators receive three years' training in general agriculture after they have passed Standard VI in academic and industrial subjects. A Standard VI pass may be achieved in eight years if there are no hitches. Altogether the demonstrator has 11 years of education at various types of schools.

When the demonstrator is first posted to a reserve which is relatively undeveloped he is expected to supervise 16 demonstration plots. He recruits 16 African farmers who are prepared to adopt improved agricultural methods. To start with only a part of the land (commonly two acres) is worked as a demonstration plot, but every encouragement is given to the farmer to work all his land on improved lines. The farmer agrees to follow the advice of the demonstrator and to allow him to measure the crop yields. All the grain and produce of the land belongs to the farmer who works the land.

The farmer first constructs any necessary soil conservation works. He ploughs and cultivates the land at the correct time. He adopts an approved crop rotation, which includes an application of manure at the rate of 10 tons per acre on one-quarter of the land each year. He plants the crops at

correct distances and keeps the land weed-free. The demonstrator visits him regularly thoughout the year and shows him how to carry out these practices correctly.

The demonstrator keeps a ' plot record book ' in which each plotholder is recorded in the following form :

Crop Record	*DEMONSTRATION PLOT, No. 13*				
	Plotholder ANAFE				
	1	2	3	4	5
Crop grown	Maize	Sorghum	Groundnuts	Eleusine	
Acreage of land	½ acre	½ acre	½ acre	½ acre	
Amount of compost used ..	5 tons	—	—	—	
Date of planting	28 Nov.	29 Nov.	2 Dec.	20 Nov.	
Percentage of germination	90	85	90	Broadcast	
Total yield (bags of grain)	7	3½	4½	1¾	
Yield per acre	14	7	9	3½	
Remarks (insect damage, disease, witchweed, *etc*)	Eleusine dry planted. Good rains 27 Nov. to 4 Dec. followed by dry spell to 16 Dec. then fairly good season. Maize attacked by stalkborer but not severe. Eleusine affected by witchweed.				

(Yields are measured in bags of 200 lb. except unshelled groundnuts, which are 65 lb.).

In this plot record book he is also required to report other information for his area, such as the number of farm carts in use, new buildings constructed, lined wells made during the year, the rainfall record and similar annual statistics.

The 16 demonstration plots must be widely scattered in the area and the owners are called plotholders. After four years of instruction and advice the plotholder is presumed to be efficient and the demonstrator replaces him with another recruit. The plotholder may then qualify to become a ' master farmer ' if all his land is cultivated the way he has been shown and if he also manages his stock efficiently and improves his living conditions. Master farmers are issued with a badge and a certificate and these awards are made at public meetings and are highly prized.

The demonstration plots are a constant example to the farmers round about. The agricultural demonstrator arranges meetings at the plots to encourage others to adopt these improved methods. All the work on the plot is done by the farmer, his wife and his family without government assistance other than the advice of the demonstrator and hence it is found easier to persuade other farmers to adopt these improved methods. Annually more formal pre-harvest meetings are arranged at one of these 16 plots and attended by the District Commissioner, the Land Development Officer, the supervisor and agricultural demonstrators. Plotholders, master farmers, other farmers and their wives come in their hundreds to these meetings. Other farmers who adopt improved methods of agriculture are called co-operators and are also advised and helped by the agricultural demonstrators. At the end of 1952 there were 3,570 master farmers, 3,866

plotholders and 67,464 co-operators out of an estimated total of 280,000 African farmers.

When a reserve becomes more developed the job of the agricultural demonstrator becomes more complicated. The demonstration plots still serve an extremely useful purpose in these better developed areas as it is always possible to demonstrate a standard higher than that of the surrounding farmers. Nevertheless the demonstrator is no longer required to concentrate all his energies on the demonstration plots and he becomes more a general extension worker. He visits all the farmers in his area. He tells the master farmers about more advanced methods and encourages the unprogressive, conservative farmers to take one or two steps up the ladder of progress. He plays his part in the organization of food drives, in cattle improvement schemes and in general community advancement.

In Purchase Areas the work of the agricultural demonstrator does not follow the usual pattern. In these areas the farmer buys his land and he is a more progressive man. There are over 5,000 of these men on their own land and there is no need for demonstration plots on the farms. The demonstrator is an extension worker right from the start and he cannot cope with more than 100 farms. There is usually a Farmers' Association in the Purchase Area and the demonstrator attends all their meetings as an adviser.

He visits each farmer regularly, discusses his problems and helps him. He finds that he has to give advice on farm lay-out, building construction, the setting out of orchards, establishment of small eucalypt and conifer plantations, improved farming practices, stock management and poultry breeding. He is also required to give special help to one farmer who has agreed to develop his farm as a demonstration farm.

The demonstrator is helped in his work by the visits of mobile cinema vans. Films made by the Central African Film Unit dealing with agriculture and related subjects are included in their programmes. He is also encouraged to make use of all the simpler visual aids and to win over the farmer by adopting the right sort of approach.

The advancement that has taken place in agriculture in Reserves and Purchase Areas in Southern Rhodesia has been due to the work of the African agricultural demonstrators guided by supervisors, under Land Development Officers, and no account of this development would be complete without acknowledging the pioneer work organized by E. D. Alvord, the first Director of the Department of Native Agriculture.

ACKNOWLEDGMENT

The writer is indebted to R. M. Davies, Director of the Department of Native Agriculture, for permission to publish this article.

(*Received December 1953*)

REFERENCE

Department of Native Agriculture, Annual Reports, 1947 and 1952.

Tea Research Problems in East Africa

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CONDITIONS AND ORGANIZATION OF TEA INDUSTRY IN RELATION TO RESEARCH

Any attempt to define tea research problems in East Africa would be meaningless without some preliminary description of the diversity of conditions under which tea is grown in the territories of Kenya, Tanganyika and Uganda. Also relevant to the subject is some account of the framework, technical and administrative, within which a small commodity research station must work.

Agricultural development in East Africa followed the building of the Kenya–Uganda railway at the turn of the century, and of the Tanga railway in Tanganyika a few years later. Tea is a relatively late comer in these territories and although specimen plants were established in Kenya as early as 1904, it was not until the years 1923 to 1925 that commercial cultivation really started. In comparison with coffee and sisal the tea industry is small ; at the end of 1952 the acreages involved were, in thousands: Kenya 21·0; Tanganyika 10·4; and Uganda 7·8[1]. As usually happens under these conditions, the major industries absorbed the lion's share of the technical assistance available from the developing colonial agricultural departments, and no comprehensive research into tea problems was started until the foundation of the Tea Research Institute of East Africa in the period 1949–51, dates which refer to the period of organization preceding the formal incorporation of the Institute.

The recognized edaphic and climatic requirements of tea are: well drained soils in the acid range of pH, and moderate to high, well distributed rainfall (50–200 in.) with a temperature range conducive to high humidity and absence of frost. These desiderata limit tea cultivation to a number of relatively small areas between elevations of 3,500 and 7,000 ft. where in addition to there being adequate precipitation, weathering processes have produced soils of the type defined from formations of gneiss, granite or more recent volcanic rocks.

The tea areas are widely separated, ranging from the coastal spurs of the Usambara mountains in the north east of Tanganyika to the foothills of the Mountains of the Moon on the western border of Uganda; and in a southerly direction to Tukuyu within sight of Lake Nyasa in southern Tanganyika. The distances involved in these two directions are approximately 700 miles each.

Within these areas the annual rainfalls range from under 50 in. to about 100 in.; soil types are varied and include catenary systems, as defined by Milne, in Tanganyika and Uganda. In view of what has been said it is evident that these very diverse conditions will give rise to somewhat diverse systems of tea growing with correspondingly varied problems.

The Tea Research Institute is consequently faced with a large range of *ad hoc* problems some of which cannot be put under formal investigation without continuous facilities for experiment in widely scattered areas. On the other hand, long-range researches on fundamental problems relevant to all types and phases of agriculture are no proper subject for a commodity research institute even though they vitally affect tea. Fortunately the newly constituted East African Agriculture and Forestry Research Organization which has embraced and developed the functions of the East African Agricultural Research Station at Amani, works in the closest co-operation with departments of agriculture and commodity research stations throughout the East African territories.

Forty thousand acres of tea is a small amount to support its own research station, and it says much for the foresight of the leaders of the industry that they have made provision for research at an early stage of development. In north-east India and Ceylon, the tea acreage was more than ten times this before research organizations were established there, and the tea industry had been in existence for 50 years or more when their individual research centres were founded.

The East African research station has a research staff of five and at present is divided into two departments covering general agricultural problems (including pathology), and chemical problems relating to both the growth of the plant and the manufacturing process of black tea. The research institute is situated at Kericho, the centre of what is now, and is likely to remain, the largest and most rapidly expanding tea district in East Africa. The annual revenue of the Institute, which in 1954 will amount to rather more than £16,000, represents a charge of approximately three-quarters of one per cent of the estimated turnover of the industry. This revenue is provided by the three territorial Tea Boards, which are statutory boards representing both the industry and Government, and which contribute, from the cess that they are empowered to collect, on production and acreage, in proportion to the production in each territory. The governing body of the Institute in a similar manner includes nominees of the Tea Boards and of Government, with an unofficial majority. The chairman is Sir Bernard Keen, D.Sc., F.R.S., Director of the East African Agriculture and Forestry Research Organization. To complete the picture of the administrative arrangements, the Institute is incorporated in Kenya as a company limited by guarantee without share capital, following the example of the Grassland Research Station of Great Britain.

Against this background of conditions and resources the problems of the tea industry and their attempted solution have been considered. This consideration has led to two cardinal decisions respecting the work of the Institute, of which the first is that the investigations pursued should give fundamental information applicable to the industry as a whole, and not in the first place examine the minutiae of cultural and manufacturing techniques which diverse circumstances may impose in different areas. This means, in effect, that the type of work carried out stands for the most part in between the kind that is properly the function of E.A.A.F.R.O., and purely technological experimentation. If the nature of the underlying ecological and chemical processes involved in tea culture and manufacture

is understood, the modifications in technique required by varied conditions can be planned on a logical basis. For example, work carried out in Ceylon some 20 years ago showed that recovery from pruning was directly associated with the status of carbohydrate reserves in the roots of tea, and indicated that rate of growth and cyclical resting periods had marked effects on starch reserves[2]. Relatively simple field tests have, on this basis, provided evidence for advising in different districts both time and severity of pruning operations.

The second important decision was that to cover so large an area, experiments based on a limited area of land at the Institute's headquarters would be of limited value also. The Institute has not, therefore, an experimental estate of its own. In Kericho, areas are put at the disposal of the Institute by the local tea companies and all operations are supervised by the staff. This works very well, and is not very different from the system in Ceylon where on the 400 acre estate of the Tea Research Institute of Ceylon the labour for experimental work was provided from the general estate personnel and supervised by the technical staff.

Field experimental work is also carried on or projected in the other territories. It is possible to organize the layout under the supervision of the Institute's staff, but the weekly harvesting and recording is entrusted to the estate's staff. This co-operative system is still in the trial stage. It cannot achieve the same degree of accuracy as at headquarters, but has so far provided data of adequate significance on some of the questions posed.

Cultural Problems

Soil survey in East Africa, which is prosecuted under the aegis of E.A.A.F.R.O., is still in its infancy. The late G. Milne's early work on the soil map[3] has provided a basis which is now being expanded. This map has clearly defined the soil types suitable for tea. With few exceptions estates have not had recourse till recently to manuring of the crop. Practically no analyses on tea soils are in existence, and in any event they can only provide ancillary information for use in advisory work. It may be that manurial applications, which are expensive, particularly because of long haulage costs from the ports, are on a short-term view unremunerative. Nevertheless, to crop continually in a blindfold manner a perennial monoculture such as tea is not a sound agricultural practice. There is a need therefore for field experiments which will indicate the state of balance between crop production and inherent fertility, and this aspect was the first of the investigations to be put in hand. From a study of the yields and responses obtained, guidance can be given either as to how crops can be increased by providing effective nutrients, or in the absence of response, as to the supplements required to ensure that no serious drain on soil resources is going on. At a recent fertilizer conference at E.A.A.F.R.O., Dr. E. M. Crowther emphasized that it was essential to consider manuring not only from the viewpoint of what kind and how much, but also to be assured that nutrients supplied were given a chance to work. As a start therefore factorial experiments have been put in hand to cover the five factors, nitrogen, phosphate, potash, sulphur and vegetable mulch. The relevance of the first three needs no explanation; sulphur is known to be a limiting factor in

one area and the general level of soil sulphur content is probably not high[4]. It is desired to know, therefore, whether applications of sulphate of ammonia, the most widely-used fertilizer, produce their effect by reason of the nitrogen or sulphur they contain, or both. Similarly soil moisture is a frequent limiting factor in marginal areas and the mulch treatment has given valuable information on that aspect. So far only in the Tukuyu district of Tanganyika has any response been obtained to the standard fertilizers, and even there only for nitrogen: but the experiments are so far only three years old[5]. In this connection it may be remarked that in the similar Ceylon experiments it took 11 years to demonstrate a potash exhaustion severe enough to affect yields at current levels.

deficith the exception of sulphur there has so far been no evidence suggesting Wiencies in minor elements that affect the growth of tea. The pH level of he soil has to be scrutinized with care because, particularly in the catenary systems, the bottom lands frequently have a base content that is paralleled by a pH range above 6·0 to 6·2 which is the marginal band for adequate growth of tea. Previous African cultivation and habitation in many instances also ruins land for tea culture. This is hardly a research problem at the moment. The affected areas are not usually large and are more of an aesthetic than a commercial nuisance, but it is of interest to record to what considerable depths of subsoil the effects of wood ashes from fires, and the mineralization of excreta have modified the pH of the profile[5]. Even at 5 ft., which is well below the normal feeding root range of tea, there is little amelioration of ' hut site ' reaction values and the quantities of sulphur or other improvers needed to restore normality is out of all proportion to the monetary gains and losses involved.

One of the most serious problems in East Africa is that of weeds and in particular the ravages of two prevailing ' couch grasses ', *Digitaria abyssinica* and *D. scalarum*, and the scourge of the wet tropics *Imperata cylindrica*. Infestation by these grasses is the result of bad agricultural practices when the land was opened, and eradication by intensive cultivation, the only practicable method so far, is both expensive and temporarily damaging in the extreme to already unthrifty tea.

Popular scientific articles in the press have made the general public aware of selective weed-killers and we constantly receive inquiries as to whether these can be used in tea gardens. The answer is in the negative. Research on these products seeks to perfect a chemical that will inhibit soft-leaved dicotyledonous weeds without affecting monocotyledons, notably cereals; the opposite is required for use in tea. With tea there are further complications. Contamination of the leaves of tea would lead to trouble with existing food regulations. Moreover, the weeds grow more vigorously than the tea and the original scotching by weed-killer is not helped to the same extent by the subsequent smothering competition of the main crop.

Work has been started on the possibilities of using trichloracetates on land that is being opened for tea culture. The indications of an ecological experiment of an observational type are that the couch species are checked and that subsequently the adventitious grass species and relatively harmless soft weeds multiply. Investigation is being made into the period that must

elapse between use of the T.C.A. and the planting of the main crop, and of the best climatic and cultural conditions under which to use the weed-killer.

Selection and Vegetative Propagation

In other tea producing countries the improvement of the type of tea by selection and vegetative propagation has received much attention. In particular in Ceylon and southern India the multiplication of clones showing marked resistance to the Blister blight disease (*Exobasidium vexans*) is an important line of research. The part played by a research institute in this work is mainly to devise the best methods of selection and propagation for use by estates, and to a limited extent to provide clonal material. The first of these objectives is under examination in East Africa, for the soil and climatic conditions prevailing make the task more difficult than in India and Ceylon. The second objective would need an organization on a much larger scale than East Africa can at present support. The suggestion that Africa should procure and nurture clones resistant to blister blight, against the time when the disease may arrive, is, in practical application, fraught with difficulties. Under the International Tea Agreement, the subscribing countries (where work on blister blight resistance is proceeding) are precluded from sending planting material to non-subscribing countries of which East Africa is the chief. The question of quarantine could be solved if an adequate method of transport of specimens could be operated. But it does not follow that a degree of resistance noticeable, say in Ceylon, would be reproduced in Kenya. Clonal material could only affect new plantings, and it is a reasonable conjecture that if the disease reached Africa, new planting would cease until the existing mature areas had been safeguarded from damage by the adaptation of the means adopted to control the disease elsewhere. During this hiatus East Africa could sort out its own resistant types. Nevertheless, selection and propagation as a long-term subject of inquiry is a worth-while item of the Institute's programme, particularly from the viewpoint of strains with root systems capable of resisting drought, for drought-resistant types there must be if a substantial increase in acreage and production is envisaged.

Pathological Problems

Pathological problems do not seriously worry the tea industry in East Africa at present. Tea being a new, widely dispersed crop with reasonably effective geographical barriers against invasion by insects and fungi less prolific than blister blight, even the favourable monoculture treatment has not brought about infestations of any alarming degree.

Armillaria mellea is prevalent in all ex-forest areas and investigation of its ecology has added one or two points to the classic work of LEACH[6], particularly in relation to rhizomorph extension which is more notable than Leach suggests[7]. A recent outbreak of branch canker on young tea in southern Tanganyika has suggested that the Mosquito Bug, *Helopeltis sp.*, though not defoliating large areas as in southern India, can, as in Nyasaland, bring about more serious damage than is apparent at first sight, by causing lesions that are rapidly turned into pernicious cankers by infection of parasitic and wound fungi[8].

Manufacture

In respect of experiments on manufacture, the Institute has the hospitality of local factories. Much of the work that falls to be done is of the nature of day to day technology rather than of research. For many reasons, including the less skilled labour and the absence of foremen supervisors of the manifold processes involved (*e.g.*, the ' tea makers ' of India and Ceylon), the refinements of technique usual in old-established tea countries have still to be worked out under local conditions.

The fundamental process in tea manufacture is the oxidation of catechins, brought about by an enzyme secreted in the leaf, when catechins, oxygen and enzyme are brought into reaction by the rolling process.

Delays in the fermentation process are frequently spoken of in East Africa and investigation of these has started. The enzyme responsible for the oxidation of tea catechins to the coloured and aromatic compounds found in the typical cup of tea is a copper–protein compound. To get adequate fermentation the copper content of tea leaf must greatly exceed the amounts needed for ordinary physiological processes of plant growth. Analyses in Ceylon give values between 20 and 30 p.p.m. as the norm[9, 10]. Samples analysed in Kericho range from 12–18 p.p.m. This immediately suggests that the copper status of the leaf may be subnormal from the viewpoint of enzyme formation. On the other hand, when the enzyme preparation is isolated from green leaf and its activity measured *in vitro*, the values obtained are fully as great as those found in Ceylon.[5] The resolution of this anomaly is one of the main pieces of biochemical research occupying the attention of the Institute.

The problems outlined above are a selection of those which have been tackled by the Institute which is still in the process of putting its programme in perspective.

In conclusion it will not be out of place to refer to a problem of an altogether different nature that exercises the minds of all who are associated with small commodity research institutes. The Tea Research Institute, in common with others of its kind, carries out advisory work on estates. The writer is of the opinion that in no other agricultural industry are research and practice more closely integrated than in the tea producing countries. The combination of the two activities has many advantages; the research worker sees his problems in their natural setting and from diverse points of view; the observations and ideas from which research springs are his at first hand; and, having resolved his problem, he can put his conclusions to a practical test. But sooner or later he is faced with a dilemma. The more successful his investigations, the more extensive becomes his advisory activity. The well-being and the progress of a commodity research station depend fundamentally on regulating to a nicety the amount of time and energy devoted to these two occupations which should be complementary but can easily become antagonistic.

(*Received January 1954*)

REFERENCES

[1] International Tea Committee, *Bulletin of Statistics*, June 1953
[2] Tubbs, F. R. 'Investigations on the Planting, Pruning and Plucking of the Tea Bush.' *Tea Res. Inst. Ceylon Bull. No.* 15, 193
[3] Milne, G. (1936). 'A Provisional Soil Map of East Africa.' *Amani Mem.*
[4] Beauchamp, R. S. A. (1953). 'Sulphates in African Inland Waters.' *Nature, Lond.*, **171**, 769
[5] *Tea Res. Inst. E. Afr. Ann. Rep.* 1952
[6] Leach, R. (1939). 'Biological Control of *Armillaria mellea*.' *Trans. Brit. mycol. Soc.*, **23**, 4
[7] Eden, T. (1952). 'The Control of Armillaria Root Disease in Tea.' *Tea Res. Inst. E. Afr. Pamph. No.* 3, 1952
[8] Leach, R. and Smee, C. (1933). 'Gnarled Stem Canker of Tea Caused by the Capsid Bug (*Helopeltis Bergrothi* Rent.).' *Ann. appl. Biol.*, **20**, 691
[9] *Tea Res. Inst. Ceylon Bull. No.* 29, *Ann. Rep.* 1947
[10] *Tea Res. Inst. Ceylon Bull. No.* 32, *Ann. Rep.* 1950

The Teaching of Tropical Agriculture in Europe—II: Belgium

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HIGHER AGRICULTURAL EDUCATION

The teaching of tropical agriculture at university level began in Belgium in 1900, at Louvain, on the initiative of Professor E. Leplae.* It was organized by law in 1920. At that date three institutes gave this instruction: the State Institutes of Agronomy at Ghent and Gembloux, and the Institute of Agronomy of the Catholic University of Louvain. The courses at that time lasted for four years, divided into two years of general preliminary science and two years' specialization in tropical agriculture, the same organization existing for temperate agriculture, silviculture, rural engineering and agricultural industry. In 1934 the organization was modified; the courses comprised two preliminary years, two years' specialization in agriculture, and one year's specialization in tropical agriculture, making five years in all. Finally, since 1947 the syllabus has comprised two preliminary years and three years' specialization in tropical agriculture.

In 1909 the University of Louvain had created a two-year course leading to the degree of 'Licencié en Sciences Agronomiques.' This was made statutory in 1934. In 1937 the title was changed to that of Graduate in Agricultural Science and the course was extended to three years. The law of 1947 no longer recognizes this degree, but the University continues to bestow it as an academic award.

In 1939 the University of Louvain created a doctorate in agricultural science, an example which was followed by the other institutes. This doctorate is conferred after defence of a printed thesis, based upon at least two years' research work after completing the course for 'Ingénieur Agronome'.

Let us finish this brief historical survey by noting that the University of Louvain has created in the Congo, at Kimuenza-Léopoldville, a daughter university which began work in January 1954. Agricultural courses will commence there in 1955.

The award of Diplomas

In the tropical field, the Belgian Institutes of Agronomy award the diploma of 'Ingénieur Agronome' in each of three groups—Agronomy of Tropical Regions, Waters and Forests (with tropical orientation), and Rural Engineering (with tropical orientation); and also that of 'Agrégé de l'Enseignement Supérieur'.† The Louvain Institute also awards, as previously mentioned, academic but not legal titles, for example, the

* Higher agricultural education had begun at Gembloux in 1860 and at Louvain in 1878, while the Institute at Ghent was founded in 1920.

† This may be translated as 'Fellow in Higher Education'. It is obviously intended for those who mean to enter the teaching profession, and may have tropical agriculture as their subject.—*Ed.*

' Ingénieur Agronome ', the doctorate in agricultural science, the ' Agrégé de l'Enseignement Secondaire Supérieur ', and the ' Graduate ' in colonial agricultural science. The Institute also accepts special students who follow a course in subjects which they have chosen with the agreement of the Professors' Committee. These courses must comprise a minimum of 200 hours of teaching, and students attending them receive not a diploma but a certificate stating that they have passed the examination in the selected subjects.

Conditions of Admission

These are, for the course of ' Ingénieur ', (*i*) possession of a certificate of education in Greek and Latin, Latin and mathematics, or modern science;* or (*ii*) the passing of an examination in specified subjects under the Central Board of Examiners; or (*iii*) the passing of the entrance examination for studies for the statutory degree in civil engineering.

For the doctorate in agricultural science, it is necessary to have received the diploma at least two years before and to have the authorization of the Professors' Committee.

For the course for ' Graduate ' at Louvain, it is necessary to have (*i*) a certificate entitling the holder to proceed for ' Ingénieur '; or (*ii*) a certificate in Modern Humanities (commercial section); or (*iii*) a certificate of completion of studies at the Preparatory Institute of the University; or (*iv*) to pass the entrance examination held by the Institute itself.

For admission as a special student at Louvain, the qualifications are (*i*) admissibility to the courses described above; or (*ii*) to be considered by the Professors' Committee as likely to profit from the courses at the Institute of Agronomy.

Foreign students, holding diplomas which are judged to be equivalent, are admitted on the same conditions and receive a degree as an academic award. If the equivalence of their previous diplomas is not recognized, they must pass the required entrance examination.

Programme of Studies

The preliminary examinations for ' Ingénieur Agronome ' comprise (*i*) elements of logic, psychology and moral philosophy; (*ii*) elements of descriptive and analytic geometry, calculus, theory of probability, mathematical statistics, and biometric laws; (*iii*) mechanics; (*iv*) general physics; (*v*) general chemistry; (*vi*) elements of mineralogy, geology, and physical geography; (*vii*) elements of zoology, including comparative anatomy; (*viii*) botany.

These headings are the subject of two examinations and of at least two years' study. Each of the examinations includes practical work and written papers on all the subjects concerned.

The final examinations for ' Ingénieur Agronome ' in the group ' Agronomy of Tropical Regions ' include the following compulsory subjects:

(1) Factors of agricultural production: climatology, geology and physical geography of the Belgian Congo, pedology with special reference to the

* These studies, at the middle or secondary level, last six years in Belgium, and follow on a period of six years' primary education.

tropics and sub-tropics, plant geography, taxonomy of tropical plants, plant sociology.

(2) Cultivated plants: further studies in plant physiology, general and tropical ecology, general and comparative agriculture, general agriculture of hot countries, tropical crops, general and special crop improvement, manures and fertilizers.

(3) Domestic animals: nutrition, general animal husbandry.

(4) Elements of general legislation and colonial law, political and social economy, general tropical hygiene.

(5) Colonial economics.

(6) Rural engineering: elements of topography, resistance of materials, principles of hydraulics, improvement of tropical farmlands, motors, electricity, tropical agricultural machinery.

(7) Biochemistry, general microbiology.

(8) Elements of analytical chemistry, technology of agricultural industries, and preparation of tropical crop products.

(9) General genetics, and further study in genetics.

(10) Principles of experimentation and biometry.

(11) General and tropical entomology, general and special plant pathology.

In addition, the candidate must take at least six subjects, selected from the following list and approved by the examiners:

(*a*) Further study of special crops, including seed control.
(*b*) Tropical forest gums and resins.
(*c*) General silviculture, tropical silviculture, and forest exploitation.
(*d*) Further study in animal anatomy and physiology.
(*e*) Special animal husbandry.
(*f*) Prophylaxis of infectious and tropical diseases, elements of veterinary medicine.
(*g*) Methodology.
(*h*) Further study in colonial economics, including colonial forest politics.
(*i*) Ethnology.
(*j*) General accountancy and special book-keeping.
(*k*) Supplementary topography.
(*l*) Study of materials and colonial building.
(*m*) Landscape gardening, parks and gardens.
(*n*) Elements of road and railway construction, means of transport.
(*o*) Microscopy and micro-chemistry.
(*p*) Applied microbiology.
(*q*) Physical chemistry.
(*r*) Industrial physics.
(*s*) Supplementary mineralogy, geology, and hydrogeology.
(*t*) Supplementary physical geography.
(*u*) Limnology, tropical fish culture, and hunting.

Candidates for the diploma of 'Ingénieur Agronome' in the groups Waters and Forests (with tropical orientation) and Rural Engineering (with tropical orientation) have to take a similar list of compulsory and optional subjects, many of which are identical with those in the list just given, and others adapted to their more special interests.

These headings for the final part of the course for ' Ingénieur Agronome ' form the subject of three examinations and at least three years' study. Each examination includes practical work and written papers. Candidates must present, at the time of the final examination, an essay on a question relevant to the group of subjects they are offering. This essay must be sent to the examiners at least 15 days before the date fixed for the opening of the session.

The examination for ' Agrégé de l'Enseignement Supérieur ' comprises: (*i*) presentation of a printed dissertation, original and unpublished, and of three theses or supplementary essays; (*ii*) public defence of the dissertation and theses; (*iii*) an oral lesson on a subject set by the examiners. This examination cannot be taken until at least two years after obtaining the degree which qualifies for admission to it.

The examination for doctor in agricultural science comprises the presentation and public defence of an original printed dissertation on a question related to one of the subjects studied at the Institute of Agronomy. The subject of the dissertation must have been approved by the Professors' Committee. The dissertation must be submitted to the examiners at least a month before the date fixed for the examination.

Candidates for the examination for ' Agrégé de l'Enseignement Secondaire Supérieur ' must be holders of a statutory or academic diploma awarded by a State Institute of Agronomy, or a recognized one. The examination covers (*i*) organization and methods of technical education, (*ii*) experimental pedagogics, (*iii*) history of education, (*iv*) general methodology, (*v*) special methodology of subjects taught in institutions for higher technical education. Every candidate must produce a certificate that he has had teaching practice for at least a year, under the direction of his professor of methodology in an institution for technical education. Candidates must give two public lessons on subjects announced in advance by the examiners and chosen from the syllabus of institutions for higher agricultural education. This examination can be taken at the same time as the final examination for the diploma of ' Ingénieur '.

The examination for the degree of Graduate in Colonial Agricultural Science (at Louvain only) comprises the following subjects:

(1) Philosophy and religion.
(2) Natural science: elements of physics, chemistry, mechanics, botany, genetics, zoology, animal anatomy and physiology, mineralogy, geology, and physical geography.
(3) Crop husbandry: general and comparative agriculture, climatology, pedology with special reference to the tropics and sub-tropics, manures and fertilizers, tropical and sub-tropical crops.
(4) Economics, general accountancy.
(5) Rural engineering: tropical agricultural machinery, improvement of tropical farmlands, elements of topography, motors, electricity.
(6) Agricultural technology: processing of tropical agricultural products.
(7) The Belgian Congo: geography and climatology, general agriculture of hot countries, colonial law, hygiene, and elements of tropical pathology.
(8) Questions in religious science.
(9) An essay at completion of the course.

In addition, candidates must attend at least 300 hours of courses in optional subjects chosen with the approval of the examiners and divided between the second and third years. These optional subjects can be chosen from a list of 33, more advanced than or supplementary to the compulsory subjects. They include aspects of forestry, dairying, educational science, *etc*, as well as those more strictly agricultural.

One year of university studies comprises two terms, each of 15 weeks. There are three vacations in the year: from 24th December to 6th January, Easter Monday to the third Monday after Easter, and 1st June to the first Monday in October. The examinations are held in June and in September.

AGRICULTURAL EDUCATION AT THE MIDDLE LEVEL

Middle agricultural education was first begun at Vilvorde in 1899. Later, its organization was completed and extended. At present there are two levels of study known as A1 and A2. In the teaching of temperate agriculture and horticulture a third level, A3, is recognized.

The A1 course, leading to the qualification 'Ingénieur Technicien Agricole Colonial' is so far available at two state schools, Huy and Izel, and one provincial school, Ath.

The A2 course, leading to the qualification 'Agronome-Technicien Colonial', is given in five state schools, Dixmude, Vilvorde, Melle, Huy, and Izel; two provincial schools, Ath and Waremme; and two free schools, Saint-Trond and Carlsbourg.

Organization and Syllabus of A1 Courses

These courses last three years. They are open to holders of a certificate of education in science or in Latin and mathematics, and also to those who pass an entrance examination relevant to the programme of the second scientific (penultimate) year of the course. Pupils from the A2 schools can be accepted, provided that they pass the examination mentioned.

The syllabus, spread over three years, comprises the following subjects:

(1) Elements of higher mathematics, statistics and biometry.
(2) General and experimental physics.
(3) Inorganic, organic, physical and analytical chemistry.
(4) General mechanics and mechanics applied to agriculture.
(5) Elements of thermodynamics.
(6) Electricity.
(7) Zoology, including entomology and apiculture.
(8) Phanerogamic and cryptogamic botany.
(9) Elements of geology, mineralogy, agrology, hydrology and pedology.
(10) Climatology, meteorology.
(11) General and special agronomy, general agriculture, special crops including silviculture, improvement of plants, genetics, production of seeds and selected plants, use of fertilizers, fruit culture, and market gardening.
(12) General and special animal husbandry, institutions for animal science, animal anatomy, hygiene, and pathology.

(13) Agricultural economics, sociology, general, and agricultural accountancy, co-operation, scientific organization of agricultural work, dairy economics.
(14) Rural engineering, agricultural machinery, tractor cultivation, draughtsmanship, surveying, levelling, building.
(15) Microbiology.
(16) Technology of agricultural industries.
(17) Morals, psychology, methodology, pedagogics (for training of teachers in agricultural technology).
(18) Elocution, public speaking, lecturing, reports.
(19) Political and social economy, economic geography.
(20) Origin and history of agriculture.
(21) Elements of social legislation and rural law.
(22) Laboratory, class-room, and workshop methods.
(23) Farm management and cropping plan.
(24) Work relevant to one or other branch of agriculture—a special study.
(25) Physical training.
(26) Supplementary foreign languages (for practical use).

For those who are taking this course in colonial subjects, the syllabus also includes:

(27) General tropical agronomy.
(28) Tropical botany.
(29) Ecology, fish culture, hunting, and fishing.
(30) Supplementary colonial political economy.
(31) Tropical crops.
(32) Colonial agrarian economy.
(33) Tropical entomology.
(34) Colonial rural engineering.
(35) Administrative geography and colonial law.
(36) Tropical hygiene and prophylaxis.
(37) Bantu languages.
(38) Tropical plant pathology.
(39) Tropical silviculture.
(40) Technology of tropical agricultural industries.
(41) Tropical animal husbandry.

These headings, spread over three years, are the subject of a series of numbered tests, oral and written. Two periodical examinations are held each year. The examinations at the end of the year cover all the headings in each course. The final examination includes, as well as the ordinary syllabus, the preparation and discussion of a cropping plan, and the special study made in one or other branch of agriculture.

Organization and Syllabus of A2 Courses

The courses for ' Agronome-Technicien Colonial ' last four years, that is to say three years to obtain the diploma of ' Agronome-Technicien ' and one year of tropical specialization. Pupils must be at least 15 years old at the beginning of the first year and have satisfactorily completed their lower middle studies, that is to say the three first years of secondary education. Those qualified for admission therefore have either finished their third or

fourth middle standard, or have successfully completed three years in the middle agricultural schools on the lower course A3. Pupils are also admitted who pass an entrance examination covering the subjects of instruction in the lower middle grade.

The syllabus for the A2 course comprises the following subjects :

First year.—Applied mathematics, surveying, levelling, applied drawing, native language (applied French or Flemish), mineral chemistry, physics, general agriculture, botany, morals and *savoir-vivre*, geography, history of agriculture, exterior of animals, animal anatomy, zoology, apiculture, cultivating and harvesting implements, field repair and maintenance of machines, rural building, second national language (colloquial Flemish or French), colloquial English, physical training.

Second year.—Applied mathematics, general mechanics, barn machinery, commerce and commercial accountancy, applied drawing, native language, organic chemistry, technology of agricultural industries, use of fertilizers, special crops, plant physiology, microbiology, geography and agricultural expansion, rural building, drainage and land improvement in general, exterior of animals, veterinary hygiene, diseases of animals, fruit culture, market gardening, second national language, colloquial English, physical training.

Third year.—Applied mathematics, native language, electricity, tractors and tractor cultivation, agricultural book-keeping, agrology, plant diseases of chief crops, improvement of plants and production of selected seed, economics, rural legislation and sociology, exterior of animals, animal nutrition, animal husbandry and institutions for animal science, technology of agricultural industries, silviculture and forest technology, agricultural co-operation, second national language, colloquial English, physical training.

The diploma of ' Agronome-Technicien ' is awarded to candidates who pass their third-year examination and submit a satisfactory cropping plan.

Fourth year.—General tropical agriculture, climatology and agrology of the Belgian Congo, principles of tropical botany, plant pathology and entomology, colonial rural economy, colonial law, colonial rural engineering, tropical crops, principles of selection and improvement of tropical plants, tropical silviculture, tropical human hygiene, tropical animal husbandry, studies of the Congo (geography, history and bibliography), physical training, second national language, colloquial English, Congolese languages, practical work and excursions.

Some 750 Ingénieurs Agronomes are at work in the Belgian Congo, in government service, in the ' Institut National pour l'Étude Agronomique du Congo Belge ' (' I.N.É.A.C.'), or in private enterprises. A certain number have found employment in other parts of the tropics. A still larger number of holders of diplomas from the institutions for middle agricultural education are working in the same fields.

(*Received January 1954*)

A Survey of the Cavendish Group of Bananas

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SUMMARY

An annotated list of the Cavendish group of banana varieties is given.

INTRODUCTION

The recognition of the Cavendish group of bananas as a group of varieties related to each other by somatic mutation was due to Cheesman (1933); Cheesman, Wardlaw and Spencer (1933). It was shown that the group consisted essentially of five varieties that differed from each other in stature and bract persistence. Problems and methods of varietal identification have recently been described elsewhere (Simmonds, 1953*a*) and the purpose of this report is to summarize all the available information on identity and synonymy in this important group of bananas.

The list that follows is based upon three sources, namely: (1) determination by experimental planting of introductions to the Imperial College of Tropical Agriculture over the past 25 years; (2) observations made by the writer during recent travels in the Caribbean and elsewhere; (3) the literature available. There are two disadvantages inherent in the first method; one is that errors of varietal identification or of labelling may have sometimes been made during the collection and transport of planting material to the I.C.T.A.; another that some banana varieties are heterogeneous and this will not be revealed by a single collection (see, for example, under *Robusta*, below). Mere inspection of ordinary commercial plantings, however, is not completely reliable for slight varietal heterogeneity may not be easily detectable. So far as possible, therefore, field conclusions have been checked by experimental plantings at the I.C.T.A. but it must be understood that some plants may have been received and determined under wrong labels (one certainly was) and others may have represented merely one element in a mixed ' variety '.

The choice of names poses a difficult problem and, in the absence of rules, an arbitrary choice has been made, based largely on West Indian practice. The name *Lacatan* presents particular difficulty because it does not strictly apply to the variety for which it is now generally used in the British West Indies; it has become so well established, however, that any attempt to change it would not only be futile but also confusing.

LIST OF VARIETIES*

*Extra-dwarf Cavendish**

This clone was received from the collection of Señor Bolinaga of Orotava, Canary Islands, in 1928, and has been described and figured by CHEESMAN (1933). It is a botanical curiosity rather than a useful banana. The name is merely that used in our collections. CHEVALIER (1935) has written of it under the name *Musa cavendishii* var. *pygmaea* A. Chev.

Dwarf Cavendish

General: *Chinese, Dwarf Chinese, Canary**.

Asia: *Wet-ma-lut** (Burma); *Pisang Serendah* (Malaya—WARD, 1930); *Basrai** (Bombay); *Pachawara* (southern India—HOWES, 1928); *Binkehel, Nankehel, Pandi* (Ceylon—CHANDRARATNA and NANYAKKARA, 1951); *Ai keuk heung ngar tsiu** (Hong Kong); *Banane gabou* (Seychelles—DUPONT, 1913).

Africa: *Kinguruwe*, Kiguruwe, Malindi, Kimalindi* (Tanganyika, Zanzibar—BAKER and SIMMONDS, 1951*b*, 1952); *Giuba* (Italian Somaliland—CIFERRI, 1937); *Maouz siny* (Egypt—KERVÉGANT, 1935); *Johnson* (Canary Is.—KERVÉGANT, 1935; despite Barrett's (1925) interpretation—*cf.* RIOS, 1930); *Camayenne* (French Guinea—KERVÉGANT, 1935).

America: *Ananica*, Catura, Bananeira aña, Bananeira da China, Bananeira de Tahiti* (Brazil—KERVÉGANT, 1935); *Pigmeo* (Colombia—BAKER, personal communication); *Camburi pigmeo* (Venezuela—KERVÉGANT, 1935); *Bacove rougou* (French Guiana—KERVÉGANT, 1935); *Governor** (Trinidad, Barbados, B.W.I.); *Petite naine* (French West Indies—KERVÉGANT, 1935; SIMMONDS, 1952); *Figue chinoise, Figue courte* (Haiti—KERVÉGANT, 1935); *Tuffy** (Tortola, B.V.I.); *Quashie* (Dominica, B.W.I.); *Guineo enano* (Puerto Rico—RIOS, 1930).

This is one of the most important and widespread of all banana varieties and is the foundation of several banana trades, for example, in Brazil (WARDLAW and MCGUIRE, 1933*a*), Martinique (KERVÉGANT, 1935), Hawaii (in the past (POPE, 1926) though not now exported), Queensland (WILLIAMS, 1928), Fiji (ANON., 1948), parts of French West Africa, Italian Somaliland (CIFERRI, 1937), and the Canary Islands (HOLMES, 1930). The bunches are normally cut up and crated or else parcelled in straw and paper since they are liable to bruising and wastage (see, for example, WARDLAW and MCGUIRE, 1933*b*).

CHEESMAN (1933) has described and figured a curious mutant subtype received at the I.C.T.A. from the Canary Islands and characterized by a tendency to dichotomy of the growing point. It is unstable and the character has been lost to the I.C.T.A. collections. It is known also in Puerto Rico (BARRETT, 1925). CHEVALIER (1935) wrote of this dichotomous mutant as var. *multicaulis* A. Chev. and noted the presence in the Canary Islands of two other mutants, var. *striata* A. Chev. a variegated form with

* In this list, an asterisk(*) against a name shows that plants received under that name have been grown at the I.C.T.A.

yellow stripings on the leaves, and var. *puberula* A. Chev. with a deciduous whitish pubescence on peduncle and fruits. In Martinique the existence of two forms differing in rate of maturity, height and grade is suspected (KERVÉGANT, 1935). The *Petit nain razier* is shorter and bears a later and smaller bunch than the *Petit nain jardin.* In these respects it resembles the *Extra-dwarf Cavendish*, but (since no mention is made by Kervégant of impeded or incomplete bunch emergence) can hardly be the same. Different forms of the *Dwarf Cavendish* are also said to occur in Kenya (unpublished). Experimental comparisons are needed.

Origin of the *Dwarf Cavendish* by mutation of the *Lacatan* has recently been demonstrated (GROSS and SIMMONDS, 1954).

Giant Cavendish

General: *Giant Cavendish, Giant Chinese.*

Australia: *Mons Marie* (Queensland—probably—see below and WILLIAMS, 1928).

America: *Giant Governor** (Trinidad); *Grande naine, Nain géant* (French West Indies—KERVÉGANT, 1935; SIMMONDS, 1952); *Gigante enano, Monte Cristo enano* (Puerto Rico—probably, despite BARRETT's (1925) interpretation; RIOS, 1930).

A significant export banana only in Martinique whence the fruit is shipped in parcels to France. WARDLAW and MCGUIRE (1933*b*) give an account of its behaviour in storage. A less widespread and less important variety than either *Dwarf Cavendish* or *Robusta.* CHEESMAN (1933) comments upon it; CHEVALIER (1935) notes its presence in the Canary Islands and applies the name var. *Sagotiana* Perez ex Fawcett; KERVÉGANT (1935, p. 103) figures the variety and (p. 111) its probable origin from a plant of the *Dwarf Cavendish*, but wrongly identifies *Congo* and *Robusta* (see below) with it. It is a minor constituent of some export crops of other Cavendish banana types, *e.g.* from Guadeloupe (KERVÉGANT, 1935; SIMMONDS, 1952), from Queensland (assuming that the name *Mons Marie* refers to this variety, as implied by Williams (1928) and from Italian Somaliland (CIFERRI, 1937). Probably it occurs wherever the *Dwarf Cavendish* is grown but is not always distinguished from it.

Mutation of this variety to the *Dwarf Cavendish* has recently been noted (GROSS and SIMMONDS, 1954).

Robusta

Pacific: Unnamed* (from Hawaii via Panama under the label *Manaiula* but certainly not this variety—POPE, 1926; SIMMONDS, 1953*b*).

Africa: *Mtwike* (Zanzibar—BAKER and SIMMONDS, 1952).

America: *Congo** (Surinam—CHEESMAN, 1933); *Giant Fig** (Trinidad and other West Indies, in part, the name applied both to this variety and to *Lacatan*); *Robusta** (Jamaica—LARTER, 1938); *Poyo** (Guadeloupe, in large part); *Grande naine de la Montagne* (Martinique—KERVÉGANT, 1935; SIMMONDS, 1952); *Porto-Rique* (Dominica, B.W.I., in part); *Bongolore** (origin unknown. Our plant came from Panama in 1939; the name strongly suggests a corruption of *Bongolan*—see below under *Lacatan*).

This variety is much confused with the following one and any name is liable to apply to a mixture of the two. An important export variety in Guadeloupe (as *Poyo*, in large part); and rising in importance in Dominica and St. Lucia, B.W.I., as slightly mixed plantings under the name *Lacatan*. KERVÉGANT (1935) wrongly identifies the French West Indian forms with *Lacatan* rather than with *Robusta*. The variety, as exported from Guadeloupe, carries well in straw and paper parcels but evidence mounts to show that it can also travel well in naked bulk shipment at about 58°F, just as *Lacatan* does. There has been a certain amount of prejudice against it in Jamaica which is now, however, disappearing on the realization that it is a sturdier and more wind resistant plant than the *Lacatan*, that it bears slightly earlier and larger bunches, and that it is probably not inferior to *Lacatan* in shipping quality; this last point is at present under test.

Lacatan

Pacific: *Hamakua** (Hawaii—identified by POPE, 1926, as *Congo* (see above, under *Robusta*); SIMMONDS, 1953*b*).

Asia: *Bumulan**, *Bungulan*, *Bongolan*, *Balungun*, *Banglana*, *Tomoc* (Philippines—TEODORO, 1915; CHEESMAN *et al*, 1933); *Masak hijau**, *Pisang hijau*, *Pisang embun lumut* (Malaya—WARD, 1930; *cf.* CHEESMAN *et al*, 1933); *Pisang ambon loemoet* (Java); *Klui hom kieu* (Siam—HOWES, 1928); *Thihmwe* (Burma—HOWES, 1928); *Hapumalanamalu*, *Sapumalanamalu* (Ceylon—HOWES, 1928; CHANDRARATNA and NANYAKKARA, 1951).

America: *Mastica* (Brazil—WARDLAW and MCGUIRE, 1933*a*); *Giant Fig** (Trinidad and other West Indies (in part, see *Robusta*, above); CHEESMAN *et al*, 1933); *Bout Rond** (St. Lucia, B.W.I.—CHEESMAN *et al*, 1933); *Martaban* (British Guiana, doubtfully the same as the Indian variety of the same name—CHEESMAN *et al*, 1933); *Porto-Rique* (Dominica, B.W.I., in part); *Lacatan** (Jamaica—LARTER, 1938, but probably not *Lacatan* of the Philippines since TEODORO (1915) describes that variety as different from *Bungulan* and as having a 'black epidermis on the trunk'); *Poyo géant* (Guadeloupe—SIMMONDS, 1952); *Highgrade** (River Estate, Trinidad, B.W.I.); *Monte Cristo* (Puerto Rico—BARRETT, 1925; RIOS, 1930).

This variety is much confused with the preceding one and any name is liable to apply to a mixture of the two. An important export variety in Jamaica (where alone, to the writer's knowledge, the planters recognize the existence of a *Lacatan–Robusta* varietal problem). The name is used elsewhere for a *Robusta* population or for a *Robusta–Lacatan* mixture predominantly *Robusta* in composition (*e.g.* in Dominica and St. Lucia, *q.v.* under *Robusta*). Twice suspicions have arisen that there may exist an 'extra-tall' mutant of the *Lacatan*, once in Jamaica (untested) and once in Trinidad, the supposed mutant (*Highgrade*, see above) turning out in that instance not to be different. A variegated form with yellow stripes on the leaves has been noted at Holland, Jamaica.

Jamaica is the only place known to the writer where *Lacatan* is a major export variety. Though rather more susceptible to bruising and wastage than *Gros Michel* (WARDLAW and MCGUIRE, 1933*b*), it travels quite satisfactorily under naked bulk storage at 58°F and gives a satisfactory out-turn of ripe fruit of good flavour though pale colour. It is slightly more susceptible than *Gros Michel* to Leaf Spot (this applies to the whole Cavendish group) and is also less adaptable to poor growing conditions. The basic reason for its adoption in Jamaica as an export variety (the same reaon that held in the French West Indies and elsewhere for the adoption of other members of the Cavendish group) is its resistance, indeed virtual immunity, to Panama Disease (BAKER and SIMMONDS, 1951*a*). The present Jamaican trade in *Lacatan* has been built up since the late war and production this year (1953) is expected to exceed half the total crop.

Mutation of this variety to the *Dwarf Cavendish* has recently been noted (GROSS and SIMMONDS, 1954).

(*Received January 1954*)

REFERENCES

ANON. (1948). 'Banana culture in Fiji.' *Agric. J. Fiji*, **19,** 12–14
BAKER, R. E. D. and SIMMONDS, N. W. (1951*a*). 'Banana research—Changes in outlook.' *Trop. Agriculture, Trin.*, **28,** 43–5
— — (1951*b*). 'Bananas in East Africa, Pt. I.' *Emp. J. exp. Agric.*, **19,** 283–90
— — (1952). 'Bananas in East Africa, Pt. II.' *ibid*, **20,** 66–76
BARRETT, O. W. (1925). 'The food plants of Porto Rico.' *J. Dep. Agric. P.R.*, **9,** 61–208
CHANDRARATNA, M. F. and NANYAKKARA, K. D. S. S. (1951). 'Cultivated varieties of banana in Ceylon.' *Trop. Agriculturist, Ceylon*, **107,** 1–22
CHEESMAN, E. E. (1933). 'Mutant types of the Dwarf Banana.' *Trop. Agriculture, Trin.*, **10,** 4–5
— WARDLAW, C. W. and SPENCER, G. E. L. (1933). 'The Cavendish group of banana varieties with special reference to Lacatan.' *ibid*, **10,** 218–21
CHEVALIER, A. (1935). 'Les variétés de bananiers du groupe Cavendishii.' *Rev. Bot. appl.*, **15,** 573–80
CIFERRI, R. (1937). 'Identificazione e caratteristiche delle razze di banano coltivate nella Somalia Italiana.' *Atti. Ist. bot. Univ. Pavia*, **10,** 73–123
DUPONT, P. R. (1913). 'Varieties of plantains and bananas cultivated in Seychelles.' *Kew Bull.*, 1913, 229
GROSS, R. A. and SIMMONDS, N. W. (1954). 'Mutations in the Cavendish banana group.' *Trop. Agriculture, Trin.*, **31,** 131–2
HOLMES, E. (1930). 'The Canary Banana.' *ibid*, **7,** 320–5
HOWES, F. N. (1928). 'The banana in some tropical Eastern countries—its forms and variations.' *Kew Bull.*, 1928, 305–32
KERVÉGANT, D. (1935). 'Le bananier et son exploitation.' Paris
LARTER, L. N. H. (1938). 'Banana varieties in Jamaica.' *J. Jamaica agric. Soc.*, **42,** 460–8
POPE, W. T. (1926). 'Banana culture in Hawaii.' *Bull. Hawaii agric. Exp. Sta.*, **55,** 48
RIOS, P. G. (1930). 'Cultivo del banano en Puerto Rico.' *Bull. P.R. (ins.) agric. Exp. Sta., Rio Piedras*, **36,** 58
SIMMONDS, N. W. (1952). 'Le bananier à la Guadeloupe et à la Martinique.' *Fruits d'outre mer.*, **7,** 67–9
— (1953*a*). 'Varietal identification in the Cavendish group of bananas.' *J. hort. Sci.*, in the press
— (1953*b*). 'Note on banana varieties in Hawaii.' *Pacif. Sci.*, in the press
TEODORO, N. G. (1915). 'A preliminary study of Philippine bananas.' *Philipp. J. Sci.*, C, **10,** 379
WARD, F. S. (1930). 'Banana growing in Malaya and the presence of diseases.' *Malay agric. J.*, **18,** 63–70
WARDLAW, C. W. and MCGUIRE, L. P. (1933*a*). 'Cultivation and diseases of the banana in Brazil.' *Trop. Agriculture, Trin.*, **10,** 192–7
— — (1933*b*). 'Banana storage.' *Bull. Emp. Mktg. Bd.*, **72,** 35
WILLIAMS, G. (1928). 'The banana in Queensland.' *Qd. agric. J.*, **29,** 346–67

Mutations in the Cavendish Banana Group

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It has been generally assumed that the various members of the Cavendish group of bananas have originated from a common origin by a series of somatic mutations (Cheesman, Wardlaw and Spencer, 1933); (Kervégant, 1935); (Simmonds, 1954). This inference is based mainly on the occasional occurrence of ' off-types ' in otherwise homogeneous plantings and seems to be quite well founded. The direct evidence for mutation, however, is slight. Even the observation of two different varieties growing from one stool (*e.g.* Kervégant, 1935, *p.* 111) does not prove that a mutation has occurred unless the existence of organic connection between the two varieties is also observed. It is the purpose of this note to record two proven instances of somatic mutation in the Cavendish group.

Commercial plantings of the *Bout rond* and *Giant Cavendish* bananas in the La Ceiba district of Honduras provided the material for the observations recorded here. One plant of each variety was seen to produce dwarf suckers which, when grown to maturity, proved to be the *Dwarf Cavendish.* The existence of organic connection between the mutant and the parent plant was established in each instance. Measurements summarized in *Table 1* identify the varieties (Simmonds, 1954). *Bout rond* is the *Lacatan* of Jamaica. *Giant Cavendish* is as named and the mutants are both *Dwarf Cavendish.*

Table 1. Measurements of Banana Varieties in Honduras. Eight plants each of Bout rond and Giant Cavendish were measured, one only of each mutant. Mutant 1 from Bout rond, Mutant 2 from Giant Cavendish. In brackets—measurements of various West Indian plantings (from Simmonds, 1954) *for comparison*

Name	*Identity*	*Measurements*			
		Height (dm)	*Petiole* (cm)	*Leaf ratio*	*Grade*
Mutant (1) ..	*Dwarf Cav.*	19·1 (15·3)	30·5 (21·8)	2·05 (1·99)	12 (6·6)
Mutant (2) ..	*Dwarf Cav.*	18·3	25·4	2·00	10
Giant Cav. ..	*Giant Cav.*	29·5 (19·4)	33·8 (30·1)	2·59 (2·37)	10·9 (7·6)
Bout rond ..	*Lacatan*	44·2 (30·4)	45·5 (42·8)	3·75 (3·58)	9·9 (6·0)

The Honduras plants are larger in all respects than the West Indian plants but the leaf ratios serve to identify the varieties beyond all doubt.

(*Received January 1954*)

REFERENCES

CHEESMAN, E. E., WARDLAW, C. W. and SPENCER, G. E. L. (1933). 'The Cavendish group of banana varieties with special reference to Lacatan.' *Trop. Agriculture, Trin.*, **10,** 218–221

KERVÉGANT, D. (1935). 'Le bananier et son exploitation.' Paris

SIMMONDS, N. W. (1954). 'Varietal identification in the Cavendish group of bananas.' *J. hort. Sci.*, in the press

Selection of the Oil Palm (Elaeis guineensis) in Africa

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INTRODUCTION

Hitherto, work on the selection of the oil palm in Africa has been directed chiefly towards increasing the pericarp content of the fruit, the hereditary behaviour of the relevant factors being comparatively well known, as a result of the work carried out by the I.N.E.A.C. in the Belgian Congo. It would appear, however, that the production in weight of bunches has, as yet, been little improved. In large-scale plantations, blocks planted with seed taken from natural palmeries have, under similar conditions, given bunch-weight yields comparable with those obtained from blocks planted with selected seed. This lack of improvement in production in weight of bunches manifests itself particularly in a very wide variation in the yields of individual palms of the present varieties; indeed, this constitutes one of the main causes for the relatively low yields obtained from such plantations. With a view to reducing this wide variability in individual production, the possibility of eliminating mediocre producers from nurseries before field planting, has been investigated.

The basis of this investigation may be indicated as follows. Instead of considering the annual production or total growth of a palm, or group of palms, in terms of vegetative and reproductive organs, which are not strictly comparable, the writer has suggested that the annual production may be expressed with sufficient accuracy by a single figure, namely, the weight of dry matter in the different organs. This method of expressing the potential annual production is valid if groups of plants of the same age, belonging to the same variety and growing under similar conditions, are compared. Bearing in mind the distribution of the dry matter content between the different organs in young palms not yet in production and that of producing palms, it was concluded that, at a given time and under similar conditions, the young plants, which produced the greatest quantity of leaf matter (*i.e.*, number of leaves × average leaf area) would be those, which later would give bunch-weight yields above the average.

In the first place it was necessary to establish if, for mature palms, there was a correlation between bunch production and leaf production (*i.e.*, number of leaves × average leaf area).

EVENTUAL CORRELATION BETWEEN PRODUCTION IN WEIGHT OF BUNCHES AND LEAF PRODUCTION AMONGST MATURE PALMS

Preliminary Remarks

The potential of productivity of the palms, taken into consideration in this present study is based on the 'actual production,' *i.e.* the number of bunches and female flowers present in the crown when the observations were made. This gives a valuable measure of the potential of productivity for any group, comprising a sufficiently large number of palms. Therefore, each group investigated, comprised at least 200 palms, divided into groups of 25 to 50 trees.

For each palm, the following observations were made:

(*a*) Height of the trunk, which served as a criterion for determining the real age of the palm, according to the data supplied by BEIRNAERT and VAN DER WEYEN (1941).

(*b*) Total number of leaves and visible spear leaves. With a view to making this observation comparable for all the trees, we considered only palms bearing at least one ripe bunch. Thus, it was possible to eliminate all the leaves older than that supporting the ripe bunch. In other words, we could consider that the oldest leaf was of the same physiological age in all the trees.

(*c*) Length of the youngest fully opened leaf (=the 'first' leaf).

(*d*) Average length, width and density of the pinnae.

From these several data, it was possible to calculate, for each palm, the following indexes:

Surface index of the pinna=average length × average width of the pinna;

Surface index of the leaf=surface index of the pinna × density of the pinnae × length of the leaf;

Index of the total surface of the leaves=surface index of the leaf × number of leaves.

Those observations were carried out on six series of palms:

Palms	*Series* (200 *trees*)
Adult	1
6 to 7 years old	1
5 to 6 ,, ,, ...	1
4 to 5 ,, ,, ...	2
$3\frac{1}{2}$ to 4 ,, ,, ...	1

Adult Palms

For this series of 200 trees, divided into groups of 25 palms according to actual production, there is no correlation between the production of bunches and the number of leaves and the different surface indexes. It appears, however, that the number of leaves and the surface index reach their minimum value for the group of the lowest producing palms.

Palms Six to Seven Years Old

The conclusions drawn above are also valid for palms of six to seven years old. However, it is noteworthy that for these two series and especially for palms six to seven years old:

(*i*) the value of the surface index of the leaf and of the pinna are smaller for the group of the highest producing palms than for the other groups (the group of the lowest producing trees excepted);

(*ii*) the number of leaves and visible spears is slightly superior for the group comprising the highest producing palms.

Palms Five to Six Years Old

For this series there is a marked positive correlation between the number of leaves and bunch production ; $r=0{\cdot}739$

(For $n=8$ and $P=0{\cdot}02-r=0{\cdot}715$).

But the decrease of the surface index of the leaf and of the pinna for the highest producing palms is much more conspicuous in this series of trees.

Moreover, if we divide this series into two groups, one comprising palms five to five-and-a-half years old and the other, palms five-and-a-half to six years old, we find that:

(*i*) for the group five-and-a-half to six years old, the correlation between bunch production and the number of leaves is almost non-existent;

(*ii*) for palms five to five-and-a-half years old, this correlation is very marked.

Thus, it seems that five-and-a-half to six years may be considered as an ' age of transition ' for the palms, at least, under the conditions obtaining in the north of the Central Congo Basin.

Palms Four to Five Years Old

For this series we obtained the results shown in *Table 1.*

Table 1

Palms bearing	*Average length of leaf* (cm.)	*Density of pinnae*	*Average length of pinnae* (cm.)	*Average width of pinnae* (cm.)	*Average number of leaves*	*Average number of bunches*
2 bunches and less	425	74·7	84·8	3·72	36·8	1·44
3 ,,	433	68·9	84·5	3·80	34·4	3
4 ,,	425	67·9	86·2	3·80	37·0	4
5 ,,	423·5	68·4	84·8	3·88	37·6	5
6 ,,	434	71·5	84·8	3·78	39·2	6
7–8 ,,	428	68·8	86·2	3·77	39·0	7·5
9–10 ,,	431	67·1	84·5	3·73	42·2	9·4
11 and more	430	67·6	85·3	3·70	43·5	13·0

These figures clearly indicate that there is a high correlation between bunch production and the number of leaves ($r=0{\cdot}813$). On the other hand, the decrease of the surface index of the leaf and of the pinna has practically disappeared.

A second series of palms of the same age confirmed the results reported above. Moreover, for the trees of this series, the size of the bunches has been estimated and the figures obtained indicate that there is a positive correlation for a group of trees, between the average bunch weight and the average number of leaves.

Palms Three-and-a-half to Four Years Old

In this series, there is also a very marked correlation between the number of leaves and bunch production; $r=0{\cdot}827$

(For $n=6$ and $P=0{\cdot}01$—$r=0{\cdot}834$).

In addition, the following data clearly indicate that there is also a positive correlation between bunch production and the different surface indexes, as shown in *Table 2.*

Table 2

Average number of bunches/palm	*Average number of leaves*	*Average surface index of pinna*	*Average surface index of leaf*	*Average index of total surface of leaves*
2·7 bunches	42·9=100	252·9=100	648·1=100	278·0=*100*
6·4 ,,	43·2=100·7	276·0=109·0	755·3=116·5	330·5=*118·8*
10·3 ,,	45·6=106·3	281·2=111·1	770·3=118·9	351·1=*126·3*
14·8 ,,	49·0=114·2	298·9=118·1	772·2=119·9	378·3=*136·0*

Considering the results reported above it appears that:

(*i*) amongst mature palms there is a positive marked correlation between bunch production and the mean number of leaves existing in the crown during the two first years of production, *i.e.* for palms three-and-a-half to four and five-and-a-half to six years old;

(*ii*) this correlation disappears about two years after the onset of production *i.e.* when the palms are five-and-a-half years old;

(*iii*) in very young palms—three-and-a-half to four years old—there is also a positive correlation between bunch production and the surface of the leaf and of the pinnae. This correlation disappears amongst palms four to five years old and becomes negative in palms five to six years old. This negative correlation practically disappears in palms six to seven years old and in adult palms.

These results may be explained as follows:

There is a positive correlation between bunch production during the two first years of production and the 'quantity' of leaves (number × mean surface of the leaf) *produced during the two years, preceding the onset of the production.*

In palms, as amongst the majority of plants, there is a very marked antagonism between vegetative development and fructification. This antagonism is particularly evident as between the *number* of leaves produced and the *development* of the leaf (surface of the leaf) on the one hand, and the fructification on the other hand.

Moreover, it is highly probable that this antagonism begins with the onset of rapid growth of the female flowers, *i.e.* two to three months before the flowering stage.

ANTAGONISM BETWEEN THE NUMBER OF LEAVES PRODUCED AND FRUCTIFICATION

The existence of this antagonism is concluded from the following observations.

The crown of a tree, rationally pruned, comprises, on an average, 40 to 44 leaves and visible spears. As the number of leaves produced annually varies from 18 to 24, these 40 to 44 leaves and visible spears existing in the crown represent the production of leaves during the two years preceding the time when the observations are carried out. Thus, the correlation amongst palms three-and-a-half to four years old, between bunch production and the number of leaves in the crown, is, in fact, a correlation between this bunch production and the quantity of leaves produced between the ages of one-and-a-half to two years and three-and-a-half to four years. This reasoning—*mutatis mutandis*—is also valid for palms four to five and five to six years old.

In palms older than five-and-a-half to six years *i.e.* for those, in which all the leaves were produced after the age of three-and-a-half to four years, this correlation disappears. But three-and-a-half to four years is, on an average, the age of the onset of production—*i.e.* the development of the first bunches. Moreover, if the positive correlation obtains for all palms three-and-a-half to four and five-and-a-half to six years old, it must be noted that this correlation is more ' spacious ' amongst palms which have produced, by the fact of their age, a higher proportion of leaves before the age of three-and-a-half to four years.

Palms Four to Five Years Old

Group of the highest producing palms—
Average production = 11·2 bunches;
Average number of leaves = 41·5.

Group of the lowest producing palms—
Average production = 2·2 bunches;
Average number of leaves = 34·5.

Difference in production = 9·0 bunches.

Corresponding increase of the number of leaves = 20·3 per cent.

Palms Five to Six Years Old

Group of the highest producing palms—
Average production = 15·1 bunches;
Average number of leaves = 47·1.

Group of the lowest producing palms—
Average production = 3·1 bunches;
Average number of leaves = 43·2.

Difference in production = 12 bunches.

Corresponding increase of the number of leaves = 9·0 per cent.

(1) The coefficient of variability of the number of leaves in the crown of the palms of the six series investigated also indicates the existence of this antagonism between vegetative and fruiting development. In fact, this coefficient, which is high amongst non-producing palms and the very young palms, reaches its minimum value at the age of six years—*i.e. two years after the onset* of production—and remains at this level amongst adult palms.

(2) The comparison of the number of leaves produced by Pisifera palms, and Dura and Tenera types also tends to prove the existence of this antagonism. Thus, data given by Beirnaert and Van der Weyen (1941), indicate that, up to the age of three-and-a-half years, the Duras and Teneras produce, annually, on an average, 1·2 leaves less than the Pisiferas of the same progeny. But between the age of three-and-a-half years and four-and-a-half years, *i.e.* during the year, corresponding to the onset of production, the Duras and Teneras produce 5·6 leaves less than the Pisifera which are, for the most part, practically sterile.

Thus, from those observations it is possible to conclude that:

(*a*) There obtains a marked antagonism between vegetative and fruiting development;

(*b*) As a consequence of this antagonism, there is no correlation between bunch production and the 'contemporaneous' production of leaves;

(*c*) Therefore, the correlation existing, during the two first years of production, between bunch production and the number of leaves is, in reality, a correlation between this bunch production and the number of leaves produced during the two years *before* production started.

ANTAGONISM BETWEEN THE DEVELOPMENT OF THE LEAF (THE SURFACE OF THE LEAF) AND THE FRUCTIFICATION

In this respect it is important to note the following facts:

(*a*) The measurements of the principal elements of the leaf surface were carried out on the youngest fully opened leaf (the first leaf).

(*b*) Between the time of its emergence from the growing point and the time when a leaf reaches the position of the youngest fully opened leaf, there is a lapse of at least two-and-a-half years (Yampolsky, 1922).

(*c*) During this period, the growth of the leaf is at first extremely slow, then very rapid during the three months preceding the time when the leaf occupies the position of the first fully opened leaf (Kovachich, W. G., 1953).

(*d*) Amongst young palms the surface area of the leaf rapidly increases according to age. For the different series of palms investigated we obtained the following figures:

Age of palm	*Average surface index of the leaf*
4 years	739·0
4½ years	955·0
5½ years	1108·0

But the increase in the leaf surface, most rapid in very young palms, then diminishes considerably. Indeed, if this increase between the age of four and four-and-a-half years is about 29 per cent in six months, this is only 16 per cent between four-and-a-half and five-and-a-half years in one year. Thus, if there is an antagonism between bunch production and the development of the leaf, its effect could be concealed by the normal increase of the leaf. On the other hand, as the measurements of the different elements of the leaf were carried out on the youngest fully opened leaf, it is logical to postulate that, if there really is an antagonism between leaf development and fructification, this will be more marked in palms bearing a large number of bunches than amongst those with a very low actual production. This is demonstrated by the following data.

(1) The observations made indicated that, with the exception of palms three-and-a-half to four years old, the increase in actual production is coupled with a more or less marked, but nevertheless constant decrease in the surface index of the leaf and the pinna. However, it is known that amongst non-producing palms, as will be shown later, there is equally a positive correlation between the surface of the leaf and the pinna on the one hand, and the number of leaves on the other hand; and also between the average surface of the leaves produced before the onset of the production and bunch production during the first two years.

If the antagonism between the actual production of bunches and the leaf area is not apparent amongst very young palms three-and-a-half to four years old it is because:

(*i*) the surface area of the leaf increases very rapidly and in such a way that the 'relative' decrease resulting from this antagonism is concealed;

(*ii*) the youngest fully opened leaf in palms of this age—producing their first series of bunches—is submitted to the antagonism: bunches/leaves, during only a short period in comparison with older palms.

The graph (*Figure 1*) clearly shows amongst palms three-and-a-half to four and five-and-a-half to six years, this relative decrease in the surface of the leaf and the pinna, for the different groups of trees, divided according to their productivity.

Group I =palms of low productivity (taken as a basis of comparison).

Group II =palms having a productivity higher than the preceding ones, but still inferior to the average.

Group III=palms having a productivity superior to the average.

Group IV=group of the highest producing palms.

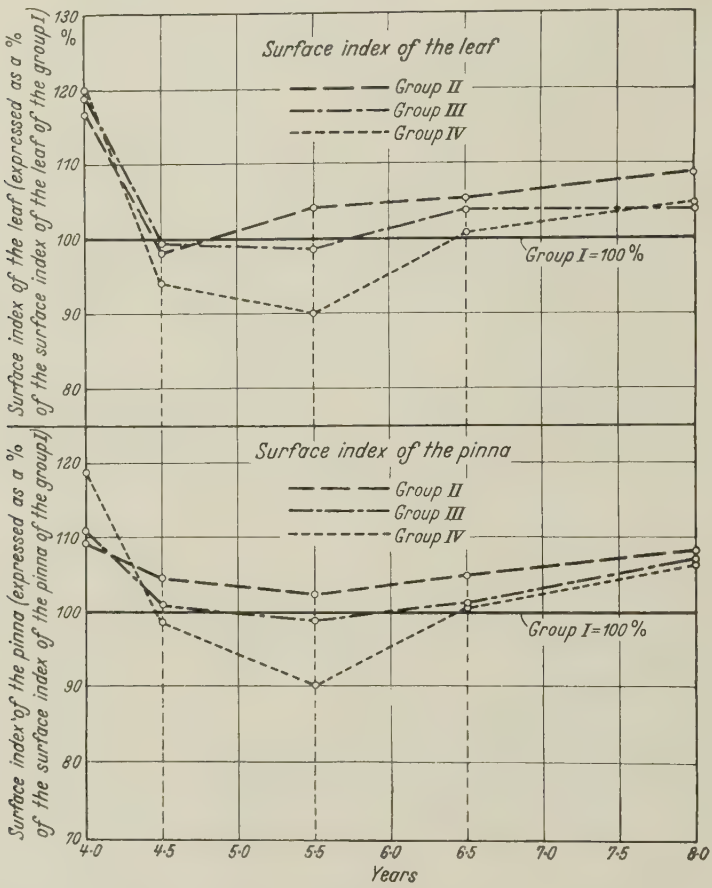

Figure 1

(2) It is also possible to demonstrate this reduction in leaf area by comparing, in young palms producing their first series of bunches, the increase of the leaf area amongst palms bearing a large number of bunches and that of trees having a low actual production.

These observations were carried out on eight series of ten palms, each series comprising five trees bearing a large number of bunches and five trees having a low actual production. For each of those palms we calculated the index surface of the leaf and the pinna for the first and the seventeenth leaf (the seventeenth leaf being taken as a basis of comparison). The results obtained are given below.

Average increase of the surface index of the leaf and the pinna between the first and seventeenth leaf.

	per cent
Pinna	
Palms bearing a large number of bunches—average increase=	0·6
Palms having a low actual production—average increase=	7·7
Leaf	
Palms bearing a large number of bunches—average increase=	11·9
Palms having a low actual production—average increase=	20·7

(3) Observations were also carried out on four palms of seven to eight years old, which had given a very high production of bunches (on an average 197 kg of bunches in four to five months). For these palms and for 10 surrounding palms, we calculated the surface index of the leaf and the pinna for the first, ninth and seventeenth leaves as follows:

Surface Index of the Leaf (expressed in per cent of the surface index of the seventeenth leaf)

Average surface index for the 10 palms taken as a basis of comparison:

17th leaf =100
9th ,, =104·5
1st ,, =103·1

Average index for the four high producing palms:

17th leaf =100
9th ,, =93·4
1st ,, =88·7

Surface Index of the Pinna

Average surface index for the 10 surrounding palms:

17th leaf =100
9th ,, =102·2
1st ,, =97·8

Average surface index for the four high producing palms:

17th leaf =100
9th ,, =94·9
1st ,, =86·2

Finally, the correlation between the leaf area and production varies as follows:

positive amongst palms 3½ to 4 years old
nil ,, ,, 4 to 5 years old
negative ,, ,, 5 to 6 years old
hardly conspicuous in palms more than six years old
practically nil amongst adult palms

This is due chiefly to the combined action of the following factors:

(*a*) the correlation between the surface of the leaves produced before the onset of production and bunch production during the first two years;

(*b*) the antagonism between leaf development and 'actual' production;

(*c*) the importance of the continuous increase in leaf surface in relation to the age of the palm. Thus, the decrease in the leaf resulting from the antagonism: bunches/leaves, will be more or less, or not, conspicuous;

(*d*) the duration of the action of this antagonism:

(*i*) amongst palms four years old, this antagonism lasted for a maximum period of nine months, *i.e.*

flowering stage to maturity of the bunch=6 months
onset of rapid growth of the female flower to the flowering stage=3 months;

(*ii*) in palms four-and-a-half years old, lasted during 15 months;
(*iii*) in palms five-and-a-half years old this antagonism lasted during 27 months, in fact, during the whole period of development of the leaf. The trees of this group, show a more marked decrease in leaf surface as a function of bunch production.

Finally, for the groups of palms, older than six years and especially in adult palms, the correlation, leaf area/bunch production, practically disappears as a relative equilibrium is established between the vegetative and fruiting development. This question will be dealt with in more detail in the second part of this note.

CORRELATION BETWEEN THE BUNCH PRODUCTION AND THE 'QUANTITY' OF LEAVES PRODUCED BETWEEN THE TIME OF PLANTING AND THE ONSET OF PRODUCTION

The results of the above observations have led to the conclusion that there is a net correlation between bunch production during the first two productive years and the quantity of leaves (number of leaves × average leaf surface) produced by this group during the two years *before* production started. The data from an experiment designed by J. D. Ferwerda (Agronomist of this Research Department) confirm this conclusion.

This experiment was laid down to determine the best method for replanting old oil palm plantations. From the beginning, the number of leaves produced, the length of the leaves and, later, the number of male and female flowers and bunches, were recorded every six months for the individual palms. Thus, it was possible to calculate for the palms in the plots receiving the same treatment:

(1) The total number of leaves produced before the onset of the production.
(2) The total number of male and female flowers and bunches recorded during the first three periods of six months each following the onset of production.

The palms receiving the same treatment were divided in four groups, according to the total number of leaves produced before production started.

Group I = palms having produced a large number of leaves
Group II = ,, ,, ,, ,, number of leaves superior to the average
Group III = ,, ,, ,, ,, number of leaves inferior to the average
Group IV = ,, ,, ,, ,, small number of leaves

The results obtained are shown below:

	Average number of leaves produced before production started	*Average number of female flowers and bunches*	*Average number of male flowers*
Treatment A (Felling the old palms)—Four plots			
Group I ...	44·0	4·0	5·8
Group II ...	37·5	1·6	3·2
Group III ...	32·2	1·05	1·9
Group IV ...	25·6	0·25	0·4

	Average number of leaves produced before production started	*Average number of female flowers and bunches*	*Average number of male flowers*
Treatment B (Felling the old palms+fertilizers)—Four plots			
Group I ...	54·3	7·4	13·2
Group II ...	47·1	6·6	10·2
Group III ...	41·7	3·3	7·8
Group IV ...	32·7	1·9	4·0

Thus, for each of the plots there is a net correlation between the number of female flowers and bunches recorded during the three periods of six months after the onset of the production and the total number of leaves produced before production started. As, on the other hand, there is a correlation between the average length of the leaves and the number of leaves produced, the data from this replanting experiment clearly confirm the results previously obtained.

From the same experimental data the conclusion may also be drawn that there is a positive correlation, for all the plots and treatments, between the quantity of leaves produced before the onset of production and the average precocity of the palms of this group.

For all plots the following mean figures were obtained.

Total number of leaves produced in three years before production started:
Average for all the palms observed=42·7 leaves
Average for the palms bearing bunches less than three-and-a-half years after planting=49·0 leaves
then, a difference of 6·3 leaves or 14·7 per cent of the mean in favour of the precocious palms.

Finally, consideration of the data has led to the conclusion that there is a constant relation between the number of leaves produced during any period, *e.g.* six months before production started, and the total number of leaves produced between the time of planting and the onset of production.

This is clearly shown by the following data:

Table 3

Quantity of leaves produced in three years before the onset of production	*Mean number of leaves produced (expressed as a % of the average for the period)*					
	Oct. '48 *to April* '49	*April* '49 *to Oct.* '49	*Oct.* '49 *to April* '50	*April* '50 *to Oct.* '50	*Oct.* '50 *to April* '51	*April* '51 *to Oct.* '51
	%	%	%	%	%	%
Group I=palms having produced a large number of leaves	122·5	126·6	129·1	128·0	124·7	121·0
Group II= production of leaves superior to the mean.. ..	107·8	108·2	108·8	105·2	106·4	107·3
Group III=production of leaves inferior to the mean	94·7	90·0	89·6	94·6	94·6	95·1
Group IV=palms having produced a small number of leaves	75·1	77·0	73·5	70·1	76·3	75·6

CONCLUSIONS

From the data recorded above, the following conclusions may be drawn:

(*A*) 1. For each group of palms growing under the same conditions, there is a net correlation between the number of leaves in the crown, and bunch production during the first two years.

2. This correlation disappears about two years after the onset of fruiting due to the antagonism between the production of leaves and bunch production.

3. This correlation is, in reality, one between the bunch production during the first two years of production and the number of leaves produced during the two years before production started.

4. There is also a positive correlation between the number of leaves and the leaf area of those produced before the onset of fruiting and, consequently, between this surface area and bunch production during the first two productive years.

5. Amongst producing palms this correlation between surface area and bunch production also disappears due to the antagonism between the vegetative development and the fruiting of palms.

6. Finally, there is a marked correlation between the *quantity* (number $\times$ mean leaf area) of leaves produced during the two years *preceding* the onset of fruiting and bunch production during the first two years *following* the onset of production.

(*B*) 1. The quantity of leaves produced before production started, *i.e.* ' the potential of leaf production ', is a constant genetical factor in a palm or group of palms.

2. The quantity of leaves produced during any period—*e.g.* of six months—before production started, is correlated with bunch production during the first two productive years.

(*C*) There is a positive correlation between potential leaf production before the onset of fruiting and the average precocity of the palms of any one group.

(*D*) As there is a high positive correlation ($r > 0{\cdot}9$) between the cumulative production over two years and the average total yield during 12 consecutive years (Van der Weyen, 1953), the final conclusion may be drawn that *there is a positive correlation between the quantity of leaves produced by a group of palms during any period before fruiting begins and the weight of bunches produced by this group in later years.*

If differences in leaf production are sufficiently apparent at the nursery stage, and the present observations indicate that such is the case, then we have at our disposal a rational and practical criterion to be applied to the selection of plants in the nursery before field planting.

VARIABILITY OF THE NUMBER OF LEAVES AND THE HEIGHT OF THE PLANTS IN NURSERY

With a view to determining precisely the variability of these factors and the most opportune moment to carry out the selection of plants in the nursery, observations were made on seven series of nursery palms from four to twelve months old. As an example, the figures obtained for plants of four, eight and twelve months old, are as follows:

Nursery Palms Four Months Old

Number of plants investigated (replacement and abnormal plants discarded) = 250.

Number of leaves	*Frequency*	*Average height* (cm.)
4	3	20·0
5	41	22·7
6	101	23·9
7	81	25·5
8	23	27·0
9	1	24·0
Mean = 6·3 leaves		Mean = 24·5 cm.

Coefficient of variability of the number of leaves = ±17·1 per cent

Coefficient of variability of the height of the plants = ±5·5 per cent

Palms Eight Months Old

Number of leaves	*Frequency*	*Average height* (cm.)
8	1	31·0
9	10	33·6
10	28	45·1
11	43	52·4
12	50	60·3
13	58	64·3
14	39	65·4
15	14	68·1
16	6	74·5
17	1	78·0
Mean = 12·3		Mean = 58·6

Coefficient of variability of the number of leaves = ±13·6 per cent

Coefficient of variability of the height of the plant = ±15·5 per cent

Palms Twelve Months Old

Number of leaves	*Frequency*	*Average height* (cm.)
12	1	53
13	1	26
14	4	73
15	3	70
16	1	82
17	12	102
18	16	98
19	13	118
20	21	134
21	24	127
22	34	143
23	27	143

Number of leaves	*Frequency*	*Average height* (cm.)
24	18	152
25	11	158
26	6	155
27	4	147
28	3	149
29	1	170
Mean = 21·3		Mean = 131·0

Coefficient of variability of the number of leaves = ±15·0 per cent

Coefficient of variability of the height of the plant = ±17·5 per cent

The variability of the factors: 'number of leaves' and 'height of the plants'—in practice, the length of the most fully developed leaf—is high amongst young nursery palms. But, in order to facilitate the selection in the nursery, differences should be well marked and the spread of the frequency curve sufficiently pronounced. The results reported above indicate that those conditions are realized when the nursery palms reach the age of eight months and more.

On the other hand, counting the leaves of each plant is tedious and difficult to perform in palms older than seven to eight months. Moreover, in large plantations, the number of plants produced per annum may reach several hundred thousand. On this account, an attempt was made to establish a correlation between the quantity of leaves produced during a given period and the height of the plant, *i.e.* the length of the most fully developed leaf, which is easy to determine. Actually, the length of the leaf is the principal factor determining leaf surface, which, as shown above, is correlated with bunch production. The results obtained are shown in *Table 4.*

Table 4

Age of nursery palms (months)	*Correlation coefficient value*	*Corresponding value of 't'*
4	0·045	0·708
5	0·103	1·640
6	0·110	1·760
7	0·118	1·885
8	0·133	2·133
10	0·156	2·492
12	0·261	3·948

For $n=250$ and $P=0{\cdot}1$ —$t=1{\cdot}645$

$P=0{\cdot}05$ —$t=1{\cdot}960$

$P=0{\cdot}02$ —$t=2{\cdot}326$

$P=0{\cdot}01$ —$t=2{\cdot}576$

$P=0{\cdot}001$—$t=3{\cdot}291$

These results indicate that, whereas there is almost no correlation between the quantity of leaves produced and the height of the plants at four months, there is a very marked correlation ($P=0{\cdot}001$) at 12 months (corresponding to an average height of the plants of ± 130 cm). Then it may be concluded finally that : '*a rational selection can be carried out at the nursery stage, based on the correlation between the height of the plants at one year old and later production in the plantation, provided all other conditions in the nursery are equal*'.

INCREASE IN THE BUNCH PRODUCTION RESULTING FROM THE RATIONAL APPLICATION OF THE CRITERION 'PRODUCTION OF LEAVES DURING A PARTICULAR PERIOD BEFORE THE ONSET OF PRODUCTION'

At the present time there are no experimental data to determine exactly the increase in bunch production resulting from the application of the criterion 'production of leaves during a particular period before the onset of production'. But those obtained from the replanting experiment previously mentioned, and the results of the observations reported above, indicate that, by eliminating in the nursery, 50 per cent of the *normal* plants, it should be possible to increase bunch production by about 40 per cent. However, it must be noted that this figure is only an indication, valid for the conditions prevailing in the north of the Belgian Congo and for the 'varieties' (Yangambi) cultivated in this region. Further, as shown previously, a selection in the nursery based on this criterion, also increases the average precocity of the 'selected' palms.

Remarks

A selection in the nursery, carried out along the lines indicated above, must be made amongst the plants of the same age growing under the same conditions. The following method is recommended for large plantations:

(*i*) to divide the nurseries into plots, each comprising the number of plants—allowing for selection—required to plant one hectare (this number of plants being fixed according to the 'severity' of the selection to be carried out);

(*ii*) to consider each of these plots as a 'unit' which must be treated as uniformly as possible, *i.e.*:
- the planting must be carried out on the same day for any given plot;
- the intensity and the duration of the shade;
- watering, mulching and application of fertilizers;

(*iii*) to make no replacements in nursery, or only during a very short period after the planting;

(*iv*) to treat the plants, at least during the first five to six months, with an insecticide and a fungicide in order to prevent 'external factors' interfering with the growth of the plants and thus impairing the comparison between them.

From the observations made during this study, some inferences have been drawn regarding the antagonism between vegetative development and the

fruiting of palms. These and the corollaries implied would seem to suggest that this antagonism affects the number of leaves produced, the leaf area of the developing fronds and the rhythm of development in the growing leaf. The evidence also suggests that the onset of production—mainly the active growth of the first female inflorescences—constitutes the start of a critical period for the palm, creating a physiological disequilibrium, which only completely disappears after two-and-a-half years. The incidence of this physiological condition and the antagonism between fruiting and vegetative development have also thrown new light on the pathological condition known as Little Leaf. Lastly, the criterion of selection in nurseries may be used to advantage in the selection and breeding of high-yielding palms, the procedure being essentially based on the hereditary transmission of gene-complexes.

Those questions constitute the second part of the present study, which will be published later.

ACKNOWLEDGMENTS

The writer is indebted to Société Anonyme Huilever for permission to publish this report, to Professor C. W. Wardlaw and S. de Blank, Director of this Department, for their help in preparing it for publication, and to J. D. Ferwerda for permission to utilize and to include the data obtained from his experiments.

(*Received November 1953*)

REFERENCES

Beirnaert, A. and Van der Weyen, R. (1941). 'Contribution à l'étude génétique et biométrique des variétés d'Elaeis Guineensis Jacq.' *I.N.E.A.C. Ser. Scient. No.* 27, pp. 53–56

Kovachich, W. G. (1953). 'Little leaf disease of the oil palm in the Belgian Congo, Pt. 2.' *Trop. Agriculture, Trin.*, **30,** 1–3

Van der Weyen, R. (1953). 'Le croisement "Dura × Pisifera" et ses premiers résultats.' *Bull. d'information de l'INEAC*, **2,** 129

Wilbaux, R. (1937). 'Les besoins du palmier à huile en matières nutritives.' *Bull. Agric. Congo Belge*

Yampolsky, C. (1922). 'A contribution to the study of the oil palm—Elaeis Guin. Jacq.' *Bull. Jard. bot. Buitenz.* Serie II, **5,** 114

The Modern Method of Hermetic Storage

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INTRODUCTION

The discovery in early times of a foodstuff which could be kept for future use without deteriorating, set the stage for the civilization of man. He no longer had to rely on hunting for game but turned to a more static existence based on the planting, harvesting, and storage of grain.

In many countries, including the Middle East lands of ancient times, grain has been hidden away in holes dug in the ground. These native pit stores were often dug in the ground which formed the floor of the primitive dwelling places and were probably adopted because this was the place from which grain was least likely to be stolen. The sites of the pits were often on elevated positions and in sandy soil, and as this method of storage was used mainly in the arid regions of the world, it was fairly successful. In many cases, however, a layer of grain round the periphery of the bulk stored became damp and was spoilt; also, insects often consumed quite a large proportion of the grain stored.

Through experience, therefore, it was found that grain in storage deteriorates through two main causes, (*a*) development of moulds and fungi when the moisture content of the grain is above a certain safe minimum, and (*b*) the presence of insects which eat and contaminate the grain and cause it to heat.

It has frequently been suggested over the past 50 years, on theoretical grounds, that airtight storage is one of the methods most likely to yield success in the control of insects and micro-organisms. During the past 20 years, in an endeavour to prevent deterioration, attempts have been made to store grain in airtight pits in the ground, in airtight silos above ground and even in airtight containers under water. These three methods rely on the same principles for their success, but we propose to discuss the first two only.

PRINCIPLE OF THE METHOD

Grain is alive, and is always respiring. When grain is dry and uninfested with insects the rate of respiration is very low. When insects are present in grain they use up oxygen and produce carbon dioxide, water and heat. Damp grain respires at a high rate, largely because the high moisture content allows fungi on and in the grain to develop, and in so doing they similarly use up oxygen and produce carbon dioxide.

Thus if damp or insect infested grains are kept in an airtight container, in time all the oxygen will be replaced by carbon dioxide which will accumulate

in the container. Respiration of the insects and fungi will be suppressed when the oxygen and carbon dioxide concentrations reach certain minimum and maximum levels respectively. Therefore, the efficacy of the airtight system depends on the factors which cause deterioration of the grain, killing themselves off as a result of their own respiration.

It can be shown that when infested grain is placed in an airtight container the insects, by their respiration, reduce the oxygen from 20 per cent to less than 1 per cent of the atmosphere in the container, and at the same time increase the carbon dioxide concentration to about 18 per cent, under which conditions they are killed. Death is not caused by the high concentration of carbon dioxide alone, for with sufficient oxygen available some insects can tolerate up to 30 per cent carbon dioxide.

In practice, the carbon dioxide concentration, which is easier to measure than the oxygen concentration, builds up quickly, the speed of build-up depending on the degree of infestation, the heavier the infestation the quicker the build-up of carbon dioxide and the depletion of oxygen.

With micro-organisms such as fungi, the rate of build-up of carbon dioxide may be more rapid than with insects because of the anaerobic respiration that can occur. Even before all the oxygen is used up, anaerobic respiration may begin and produce appreciable quantities of CO_2. This results in an increase in pressure, relief of which must be allowed for in any form of storage bin used for damp grain. Fungi will not, in general, increase to any appreciable extent at relative humidities below 75 per cent, but above this the rate of growth increases rapidly with rise in humidity. Above 75 per cent relative humidity growth of fungi is very much more influenced by the moisture content of the grain, and therefore by the relative humidity of the atmosphere, than is the growth of insects.

HISTORY

Underground Pits

The early underground pits were almost certainly not airtight, although no measurements of carbon dioxide concentrations have ever been made in these primitive structures. It is most likely that their success was due to the fact that it was only dry grain that was stored and that any heat produced by the metabolism of the insect population in the grain, would not readily dissipate from the bulk and thus a temperature lethal to insect life would be built up and self sterilization of the bulk obtained.

During the nineteenth century a number of attempts were made in France to store grain in underground containers. (Mannessier, 1950). In 1850, Doyère constructed six underground silos of concrete lined with closely riveted metal plates, and kept home-grown (French) grain in them successfully, without attention, for a period of five years. Following his recommendations, underground silos of this type were built for garrisons at Toulon, Cherbourg, Metz and Brest, and for prisons at Mettray and Casablanca, where they remained in use for 10 years or more. In 1871 the General Omnibus Company of Paris, confronted with the necessity for storing oats for the very large number of horses it maintained, built a number of silos of concrete lined with metal plates bolted together. Some were subterranean and others only half below ground. Generally speaking storage

was satisfactory, but some of the silos failed because the bolted construction was not always completely airtight, and thus when the surrounding ground was damp there might be a transference of water vapour through the wall and an increase in the moisture content of the stored grain. Probably because of these failures the method was not adopted to any appreciable extent, and no further progress was made in France for about 60 years.

In 1929, at an experimental station in the U.S.A., a pit holding 2½ tons of wheat was built of concrete plastered directly on to the earth. (SHELLENBERGER and FENTON, 1952). After four months the entire mass of wheat had moulded due to the fact that the wall did not constitute a water vapour barrier.

In 1939, with the advent of the war, Argentina was faced with a serious storage problem which as far as could be seen would last many years. The outlook was one of large harvests of grain and little chance of export. The Argentine Ministry of Agriculture appointed an engineer, C. O. Lopez, to investigate methods of storing their grain harvests over many years. In 1941, after a study of the pit methods used by natives in various parts of the world and after consideration of the physical factors affecting pit storage, he recommended the construction of underground concrete storage pits designed to be impermeable to gases and to water vapour. The Ministry adopted the proposals and set up a laboratory with the sole object of studying the problems of grain storage in pits of this type.

In *Table 1* are given typical figures showing the build-up of CO_2 concentration in an Argentine pit and the eventual low level of oxygen concentration which is developed (LOPEZ, 1946).

Table 1. Rate of Build-up of Carbon Dioxide in one of the Argentine Pits

Storage (days)	*1st 70 days*	*Next 161 days*	*Next 147 days*	*Next 154 days*	*Next 112 days*	*Percentage O_2 after 644 days*
Percentage CO_2	Increase to 9·5	8·2 - 10·5	Increase to 15·5	14·5– 15·5	Increase to 17·9	1·8

In these pits, wheat and maize were stored successfully for seven years. It was claimed that there was no adverse effect on germination—samples of wheat were said to have shown 5 per cent loss in germination, and a slight discoloration. However, samples taken by Dr. E. E. Turtle of the British Ministry of Agriculture and Fisheries, when tested at Cambridge showed very low viability.

Since then pit storage has been adopted on quite a big scale in a number of South American countries including Argentina (which now has storage for about 2,000,000 tons), Paraguay, Venezuela, and Uruguay.

During the past four years, six small experimental pits have been built in British territories in Africa to determine the suitability of this method for local conditions, with a view to using storage pits to meet the need of special famine storage programmes against occasional crop failure. Tanganyika has three of these pits, Nyasaland, Nigeria and the Sudan have one each. As a result of the experiments in Tanganyika, that territory is proceeding to construct during 1953–56 pit storage to hold 11,000 tons of grain.

Above-ground Silos

It was not until 1937, however, that progress was made with hermetic silos completely above ground. In that year some carefully-planned scientific experiments with above-ground metal silos were carried out by BLANC (1938, 1939) of the French *Génie rural*. He showed that when complete airtightness was obtained, by the use of welded steel as opposed to a bolted or riveted construction, grain with a moisture content of 16·2 per cent, the dampest he could obtain, was successfully preserved over a period which included two hot summers. Furthermore, he showed that it was not necessary to sink the silos underground to eliminate the effect of daily changes in temperature. His 20 ton experimental silo was erected in a field without any protection from the weather, but daily warming of the exterior by the heat of the sun was not passed on to the bulk of the grain.

During the last few years, and without any further scientific experiments, the method has been adopted in France by several farmers and agricultural co-operatives, for use with grain much damper than Blanc's (18–19 per cent moisture content) and success is generally claimed.

We understand that above-ground hermetic steel silos are at present being used in the French Union territories in North Africa, for example, in Algiers, to preserve dry grain from insect attack.

In order to determine the efficiency of this method at even higher moisture contents, tests have been initiated at the Pest Infestation Laboratory with grain of above 20 per cent moisture (see page 157).

MODERN USE

Underground Pits

Present day underground storage is in rectangular, open topped, concrete lined pits, somewhat resembling swimming baths. The concrete is specially treated to make it impervious to water vapour and to gases such as oxygen and carbon dioxide. Dry grain is filled into the concrete pit and heaped so as to form a mound over which a layer of a waterproof material is laid and sealed on to the concrete edges (*Figure 1*). The construction of the pits has been on the following lines :

(1) The siting of the pit is so chosen that the water table is never less than 8 ft. from the bottom of the pit. Care should be taken to eliminate the possibility of a localized water table such as might occur by siting the pit on a hillside.

(2) Earth is removed in digging out the pit to a depth of about 10 ft. and is used to increase the local ground level round the pit, thus diminishing the depth to which the trench must be dug and giving a final depth of 12 ft.

(3) The floor of the pit is composed of 6 in. thick concrete and the walls are constructed of the same thickness of concrete using wood or steel shuttering. The earlier pits had the walls in two slopes separated by a horizontal ledge, which permitted economy in the use of shuttering, and had sloping ends so that trucks could be driven into them to facilitate loading and unloading. However, the necessity for loading-ramps has passed with the advent of portable grain-handling machinery and the use of vertical walls reduces the cost.

(4) The internal floors and walls are covered with two coats of bitumastic paint, sanded with fine sand and then covered with a coat of white oil paint. This is intended to make them impervious to water vapour and

Figure 1. One of the experimental 120 ton pits in Tanganyika

Figure 2. Strips of roofing material being placed on surface of grain, and sealed with bitumen to form the roof of the pit

carbon dioxide. This cannot be achieved by adding so-called waterproofing compounds to the cement.

(5) The pit is so filled that the top surface of the grain can be formed into a mound about 3 ft. high.

(6) A layer of roofing felt is laid directly on the grain surface and sealed at the edges with bitumen compound. On top of this is laid a layer of chicken wire which is then covered with a further layer of roofing felt, which is again sealed at the edges (*Figure 2*). The roof of the pit is then painted with a cheap white paint.

There are obvious improvements which could be made to this construction, especially in connection with the provision of a water vapour and carbon dioxide barrier on the efficiency of which the success of the method depends. Localized water tables may exist near ground level during torrential rain and it is therefore probably essential that methods of vapour proofing are used, which will withstand even a slight hydrostatic pressure. This can be accomplished by cloaking the outside face of the retaining wall with the vapour barrier, which necessitates wider excavation than is normal, in the process of which the solidity of the earth adjacent to the revetment is considerably reduced. Alternatively, a sandwich membrane form of waterproofing is recommended which eliminates the danger of damage to the membrane. The membrane may take the form of a continuous asphalt lining or layers of impregnated felt, jute or cotton, covered with a bitumen or pitch binder applied hot (see SHELLENBERGER and FENTON, 1952) which is applied to the inner surface of the first layer of the floor and wall during their construction. The membrane is held firmly between the inner and outer walls and can thus resist pressure from external water.

Where sandwich construction is adopted, the outer and inner walls need not be built of the same materials. In places where brick is available and is relatively cheap the outer wall can be constructed of 4½ in. brick on which the vapour barrier is dropped or laid (cement stabilized earth blocks could be used in place of brick). The inner wall could then be constructed of 2–3 in. thick concrete which might be applied by the cement gun or 'guniting' method.

Various methods of improving on the construction of pits are being investigated by the Building Research Station in collaboration with the Pest Infestation Laboratory.

In tropical climates, weevils can often complete their life history in 2–3 weeks and since one of the aims of this method of storage is to prevent loss of foodstuffs from insect attack, it is essential that the filling of the pit should be completed in as short a time as possible.

Bulk grain can be readily taken out of a pit using modern mechanical portable elevators. If the grain has been stored in the pit in bags, as it can be, a simple windlass arrangement can be used.

Underground pits are cheaper in constructional and operational costs than any other form of bulk storage. It is not easy at present to assess accurately the cost of pit storage in different parts of the world because constructional costs vary according to local conditions and the costs of fairly large pits are at present available only from the United States and South America.

In Argentina, constructional costs were £2 per ton of storage capacity,

i.e. about as cheap as the cheapest type of above-ground bag storage premises. This figure agrees well with that of £1 5*s*. 0*d*. per ton given by Shellenberger and Fenton for the United States. In Africa, the cost for pits was of the order of £3 10*s*. 0*d*. to £6 per ton stored. The pits in Africa were small, and since the smaller the pit the higher the cost per ton stored, the figures given for pit storage in Africa are maxima. Operational costs will depend on the length of storage, the availability of suitable machinery for filling and emptying the pit, and on the degree of supervision needed to exclude damp grain, and of course these will vary with the local conditions. In one African territory, labour charges for filling a 125 ton pit were 4*s*. 9*d*. per ton, and in another the cost for emptying a similar sized pit using a mechanical elevator and rebagging was 14*s*. 4*d*. per ton.

The moisture content of grain stored in pits to date has not exceeded 13 per cent. This has been laid down arbitrarily as a safeguard against possible damage by micro-organisms. The difficulty of obtaining complete airtightness with the present form of construction may preclude the use of such pits for grain of higher moisture contents, but recent work on above-ground hermetic silos suggests that a higher moisture content limit may be safe.

Above-ground Airtight Silos

Airtight above-ground silos have been used mainly for the storage of damp grain and at present their use is confined almost exclusively to France and the French Union. Two types are in commercial production. One type (*Figure 3*) consists of cylindrical steel bins made of smooth plates ; the second is composed of a honeycomb system of hexagonal bins whose vertical walls are of pre-formed ' mansard ' section steel plates (*Figure 4*), for which an economy of material is claimed. In both, the plates are welded together, generally on the site. Welded metal construction is necessary because such materials as brick, concrete or wood (or metal which is merely riveted or bolted), are not sufficiently airtight for the purpose. Both French types have pyramidal roofs with means of filling with grain, and hopper bottom or other discharge arrangements at the base.

The capacity varies according to whether the silos are designed for individual farms or for the large co-operatives. Generally four to twelve bins, each holding 100 to 150 tons of grain are erected on each site. Usually the bins are in the open with no protection from the weather, but sometimes they are enclosed in a building of light construction, or a penthouse is erected over the upper working parts (*Figure 4*). Such protection is, however, not necessary, except for the comfort of the operators. When exposed to the atmosphere the exterior walls are usually painted with aluminium paint to reflect much of the solar radiation. It is not necessary to treat the insides of the bins ; users of the silos maintain that the natural greasiness of the grain prevents the inside walls in contact with the grain from rusting. All inlet and outlet manholes or spouts are firmly sealed with bolted covers and rubber gaskets. Each bin is fitted near the top with a pressure release valve, to prevent distortion of the silos through development of abnormal pressures inside.

When storing damp grain it is important that the bins are completely filled

with grain, or there may be condensation on the walls of the unfilled portion. Also, in a partly filled bin there might be insufficient grain to cause an adequate build-up of carbon dioxide and removal of oxygen in the free air space to prevent the further development of any moulds or insects present.

About 18 months ago one of the writers (Hyde) was able to examine several of the modern French installations and form some opinion of the method. The general conclusion was that damp wheat is considerably better preserved by the hermetic method than by storage under ordinary conditions.

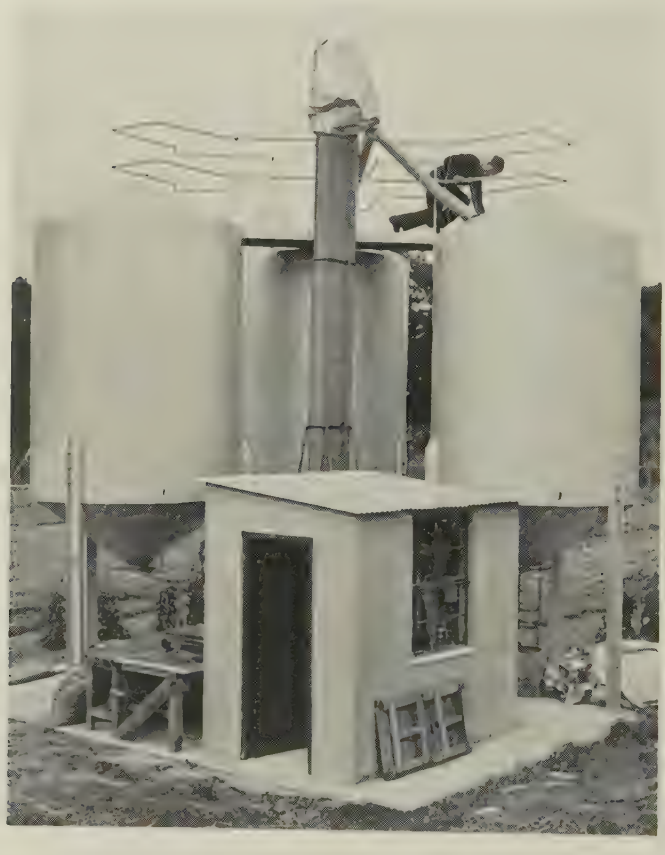

Figure 3. Experimental 10 ton silos at Pest Infestation Laboratory based on a French design

In both types of silo, round or hexagonal, grain with moisture contents of up to 18–19 per cent had been stored for periods of up to eight months when examined, and although it had in all cases developed a 'sweet-sour' alcoholic smell, which is characteristic of damp grain stored hermetically, it was normal in appearance, free-flowing and entirely free from mould attack. Although the grain was apparently satisfactory for bread-making by French standards, the viability had in all cases been reduced, and the method is

obviously not suitable for storing damp grain destined for use as seed or for malting purposes.

If the moisture content of 18–19 per cent at which grain is stored, apparently successfully, in France, is indeed the upper limit for hermetic storage, the method would scarcely be an economic proposition in Great Britain or in the hot, humid climates of some tropical countries. In many seasons grain would be harvested wetter than this and farmers would still have the expense and labour of drying the grain slightly before it could safely be stored. To find out if the method can be used successfully at higher

Figure 4. French 150 ton hexagonal bins

moisture contents, the Grain Storage Section of the Pest Infestation Laboratory has initiated a series of experiments on both a laboratory and a semi-practical scale.

For the latter experiment, three welded steel 10 ton bins have been erected at the laboratory (*Figure 3*). Two of these were filled in early August 1953 with Atle wheat cut by combine at a moisture content of over 20 per cent. The temperature of the grain in the centre of each bin, and of the north and south faces is measured by means of thermocouples. The

bins are fitted with tubes through which samples of the internal atmosphere can be withdrawn for analysis. Being connected to water manometers, these tubes also enable changes in pressure to be measured. The top manholes and lower openings (covering the slide valves of the hopper bottoms) were made airtight with rubber gaskets and bolted-on covers.

As it was undesirable to open the bins during the experiment to remove samples of grain for examination, a representative sample of the bulk was sealed in a number of small aluminium cans, some immediately after harvest and some after drying to a moisture content of 14 per cent. These cans were kept in conditions as near as possible to those anticipated within the silo bins. Some were taken at intervals and opened for examination. Comparable small-scale experiments were carried out in 4 lb. domestic preserving jars kept at a constant temperature of 15°C.

The experiments are still in progress and no final conclusions can yet be drawn, but it appears from both the small and the larger-scale tests that if either the temperature or the moisture content are too high, there is some adverse and irreversible effect on the milling and baking properties of the grain.

When above-ground hermetic silos are used for the storage of grain not exceeding 14 per cent moisture content it appears from laboratory experiments that the germination and milling and baking properties would not be affected to any extent.

It is less easy to give accurate costs for the above-ground hermetic silos than for the underground pits. So far these silos have been more in the nature of prototypes and therefore more costly than mass-produced plants. The bins themselves and their foundations cost little more than ordinary (non-airtight) bins and a figure of £6–7 per ton has been quoted for the construction of hermetic bins in France. This does not include foundations for the silos nor the elevating and other necessary machinery. An overall cost of £18–20 per ton would probably be required for a complete installation.

FUTURE USES IN TROPICAL TERRITORIES

It is certain that infested dry grain, stored in underground pits (constructed on the lines outlined in this paper) for periods of several years, has, from the commercial point of view, been taken out in good condition. With improved methods of construction there is no doubt that underground storage will be a relatively cheap and effective means of combating famine throughout the world.

In discussing the underground and above-ground airtight storage systems, it may have been obvious that we have so far maintained one fundamental difference between the use of the two methods. In the underground pits, it has been stated that grain must be dry—in fact a maximum moisture content of 13 per cent has been stipulated. There are many areas in the world which produce grain which does not normally exceed this moisture content, and where this form of storage should be given careful consideration, for example, Cyprus, Gold Coast (Northern Territories), Nigeria (Northern Provinces), Nyasaland, Northern and Southern Rhodesia, Kenya, Tanganyika and the Sudan. In the case of the above-ground silos we have

talked mainly of damp grain, with moisture contents as high as 20 per cent. Why should this be ? The reason lies mainly in the fact that the pits are probably not as absolutely airtight as above-ground welded metal silos. However, it is obvious that experiments should be carried out to determine if grain above 13 per cent moisture content can be stored successfully in well-constructed pits in tropical climates. Success with these experiments would open up other parts of the world to pit storage.

In South America, maize and wheat have been stored in these modern pits, and in Africa only maize has been used. There is no reason, however, why other grains such as sorghum and millet, pulses such as cowpeas and beans, rice and paddy, should not be kept in pits. In the Sudan, cotton seed has been stored successfully in large unlined pits. There would appear to be no obvious reason why modern pit storage should not be considered for oilseed storage (*e.g.* groundnuts) under certain conditions.

At present the cost of the roofing of pits is considerable and it is therefore desirable to use a material which can be used again every time the pit is refilled. If the method of storage is for long-term famine reserve (3–4 years), for which it is ideal, this aspect is not quite so important, but if it is to be adopted for seasonal storage this roofing item will be a major one. It is possible with future improvements in the design of the roof that the storage method would be an economic proposition for seasonal storage.

The success of the above-ground hermetic silos with damp grain has been almost entirely confined to temperate climates. Until more experimental work has been undertaken it is felt unwise to propose this method of storage for wet grain in tropical climates. If future work shows that the high temperatures in tropical climates are not detrimental to a metal silo full of damp grain, this method of storage will solve a number of problems in colonial territories, especially in those territories where crops have to be harvested during the rains and where drying is a problem. There is, of course, no reason why above-ground hermetic silos should not be used at present in tropical territories for storing dry grain which is infested with insects. Good control of insect infestation will be achieved, for the same reason as with pit storage. The cost, however, will probably be higher than the cost of pit storage. If these above-ground silos are to be used in tropical climates, it is likely that use will be made of aluminium alloys.

It is clear that airtight storage is a process involving new principles of preservation which are still not fully understood. However, further scientific studies on the fundamentals of the method are now possible through the accurate determination of carbon dioxide by the method developed by Howe and Oxley (1952).

As has been indicated in this article, the suitability of hermetic storage of grain is being investigated on an experimental scale in a number of countries and there are indications that colonial territories realize the usefulness of this type of storage. Increased interest on their part will initiate improved developments of the method.

SUMMARY

Storage of foodstuffs after harvest has been practiced by man since early times. The safe storage of crops, however, has occupied his attention only over the past 50 years. Recently, the storage of grain in airtight containers, below and above ground, has shown success on experimental and practical scales. This method depends for its success on the factors which normally cause deterioration (*e.g.* insects and micro-organisms) using up the available oxygen and replacing it with carbon dioxide which accumulates in the container. At certain concentration combinations of oxygen and carbon dioxide the organisms are killed.

Concrete pits which have the walls vapour-proofed have stored grain of moisture content less than 13 per cent in good condition for several years. Grain of a considerably higher moisture content than 13 per cent has been kept in good condition in welded metal silos. It is thought that, although underground concrete pits may successfully store grain of moisture content up to about 15 per cent, they might not be suitable for the storage of grain wetter than this because they are not as airtight as welded metal silos.

The present state of knowledge and the future use of these two methods of storage in tropical territories are outlined.

(*Received February 1954*)

REFERENCES

Blanc, A. (1938). 'Essais de conservation de blé en atmosphère confinée', *C.R. Acad. Agric. Fr.*, **24,** 625

— (1939). 'Les premiers resultats d'une nouvelle série d'essais de conservation de blé en atmosphère confinée', *ibid.*, **25,** 1005

Howe, R. W., and Oxley, T. A. (1952). 'Detection of insects by their carbon dioxide production', H.M.S.O.

Lopez, C. O. (1946). 'La conservacion de los cereales y les silos subterraneos', *Inst. agr. argent. Resenas*, **7,** 43, 27

Mannessier, J. (1950). 'Silos metalliques étanches pour le stockage des grains', *Inform. Docum. agric.*, **14,** 439

Shellenberger, J. A. and Fenton, F. C. (1952). 'Underground grain storage', *Mill. Prod.*, **17,** 7, 5

The Use of Pot Tests in Research on the Fertility of Sugar Cane Soils

Paper IV : The Effect of Phosphate and Lime on the Growth, Yield and Quality of Sugar Cane

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INTRODUCTION

Sugar cane plants were grown to maturity in 40 gal. oil-drums, comprising Type 2 pot test as described in Paper I of this series. The soil used was of the same soil-type (Cunupia Clay) as that used in the experiment described in Paper III. It is a highly acid, phosphate-absorbing soil having medium-low available phosphate content, and responding markedly to phosphate fertilizer and lime when tested in pots with Sudan Grass or Maize as indicator plant. The object of the pot experiment now to be described is to compare the results obtained for sugar cane grown up to eight months of age, with those obtained with these indicator plants when treated in the same way. The phosphate treatment involved five levels of double superphosphate applied or ' placed ' in two different ways, and the lime treatment was a single high treatment with calcium carbonate. Periodic measurements of stem length and tiller counts were made, and analyses of leaf tissue and of stem juice were made at reaping time.

EXPERIMENTAL PROCEDURE

General Procedure

The soil was collected at the Government Experiment Station, Centeno, Trinidad, from a freshly ploughed field. The total weight of air-dried soil was about seven tons. The lumps were crushed and the whole soil passed through a 2 cm sieve, thoroughly mixed and divided into 40 batches each weighing 150 kg. One ton of soil was set aside for ' moulding-up ' the cane plants. Soil samples on analysis gave Truog values for available phosphate of 24 ± 3 p.p.m. P_2O_5, and reaction values of pH $4{\cdot}9 \pm 0{\cdot}1$. Other analytical values are given in *Table 1* of Paper III.

Twenty batches of soil were each intimately mixed with 1·5 kg of finely-ground high-grade limestone (' *L* ' series). The ultimate reaction of the wetted limed soil was pH 7·5. The phosphate dosages were equivalent to 0, $\frac{3}{4}$, $1\frac{1}{2}$, 3 and 6 cwt. ' double ' superphosphate (containing 40 per cent P_2O_5) per acre, or 0, 3·75, 7·5, 15·0 and 30·0 g P_2O_5 per container. (P0, P1, P2, P3, P4.) The fertilizer was added in solution from stock containing 5 g P_2O_5 per lit. In one series the phosphate solution was added to the whole of the soil ; in the other series it was added to one-third of the weight which was later placed on top of unphosphated soil contained in the drums. The ' top ' placements are designated treatment ' t '. The depth of the phosphate-treated layer in this case was about 8 in.

The experiment comprised a replication of 5 × 2 × 2 treatment combinations. The drums were set up in the open in two groups, widely spaced in two rows for each group, and were labelled 0, 1, 2, 3, 4 and 0t, 1t, 2t, 3t, 4t, for the unlimed series and 0L, 1L, 2L, 3L, 4L and 0Lt, 1Lt, 2Lt, 3Lt and 4Lt for the limed series. The 20 treatment combinations were randomized in each block.

The moistening of the batches of soil and the filling of the drums were carried out exactly as described in Paper I. When the wet season had set in and two weeks before the cane setts were planted, a furrow was made in the soil in each drum into which was placed a fertilizer mixture consisting of 25 g of ammonium sulphate (equivalent to 2 cwt. per acre, of 4,000 plants), 25 g of potassium chloride and 6 g of magnesium sulphate.

The drums were planted up on 20 June 1952. The sugar cane variety used was B 37–172. The material used was selected cane tops of equal size and weight. Each was cut up into single-eye ' seed pieces ' and the three youngest pieces were placed in the furrow of the soil in each drum and lightly covered with soil. After two weeks all the pieces had germinated satisfactorily, and after four weeks the least satisfactory piece in each drum was removed. After eight weeks the furrows were filled in, and after a further four weeks an additional amount of 25 kg of soil was used from the reserve for ' moulding-up ' the young plants. In order to maintain the optimum level of nitrogen content in the leaves throughout the experiment, an additional application of 25 g of ammonium sulphate (2 cwt. per acre) was made every eight weeks. After 16 weeks, the canes were lightly trashed, once in four weeks, at the times when growth measurements were made, and the trash cut up and added to the surface of the soil in each drum. During dry spells, daily addition of two gallons of water per drum was made.

The cane plants were reaped on 4 March 1953 when 8½ months old. The appearance of the plants at the ages of 6 and 8 months is shown by the photographs, *Plates 5* and *6*, in Paper I.

Table 1. Data for Stem Length (Total length per drum, in metres)

Age of plant (months)	*Phosphate treatments*					*Means*	*Lime treatments*		*Placement methods*	
	P0	P1	P2	P3	P4		L0	L1	M	Mt
1	0·34	0·35	0·37	0·39	0·40	*0·37*	0·37	0·36	0·36	0·37
2	2·55	2·46	2·48	3·18	3·35	*2·80*	2·82	2·78	2·79	2·80
3	11·08	10·85	10·69	12·72	11·17	*11·30*	11·16	11·44	11·36	11·24
4	16·64	16·56	16·11	18·77	16·90	*17·00*	16·82	17·18	17·04	16·96
5	19·61	19·22	19·26	21·28	19·45	*19·76*	19·47	20·05	20·22	19·30
6	24·75	23·67	24·27	25·16	24·52	*24·47*	24·49	24·45	24·67	24·28
7	27·56	26·25	27·66	30·01	27·73	*27·84*	27·24	28·44	28·30	27·38
8½	29·57	28·56	30·19	32·79	30·34	*30·29*	29·68	30·90	30·69	29·89
Totals	132·1	127·9	131·0	144·3	133·9		132·1	135·6	135·4	132·2
Index	100	97	100	109	101		100	103	100	97
Index last measurement ..	100	97	102	111	102		100	104	100	97

Measurements

Length measurements and tiller counts were made monthly. Length of stem was measured between the seed piece and the last visible ' dew-lap '. The results are given in *Table 1.* Tiller counts have been omitted from the table because they did not show any differences due to treatment. The results are also displayed in a diagram which shows, not only rate of growth in length, but also the average stem length per tiller at different times in 8½ months' growth.

Leaf Analysis

This was carried out monthly after the canes were three months old and was repeated monthly until reaping time. Leaf collections were invariably made in the early morning. Two leaves were taken from the two longest stems in each drum. The third leaf from the uppermost stem showing a ' dew-lap ' was selected. The treatment duplicate leaf samples were combined, the upper halves were cut off and discarded, the mid-ribs were stripped

Table 2. Results of Leaf Analysis

Age of plant (months)	*Phosphate treatments*					*Means*	*Lime treatments*		*Placement methods*	
	P0	P1	P2	P3	P4		L0	L1	M	Mt
(*a*) *Phosphate content of leaf-tissue (per cent* P_2O_5 *in oven-dry material)*										
3	0·45	0·51	0·50	0·51	0·51	*0·50*	0·49	0·50	0·50	0·49
4	0·39	0·43	0·40	0·41	0·42	*0·41*	0·40	0·42	0·41	0·41
5	0·36	0·37	0·36	0·36	0·35	*0·36*	0·35	0·37	0·36	0·35
6	0·38	0·40	0·37	0·36	0·39	*0·38*	0·36	0·40	0·37	0·39
7	0·34	0·38	0·37	0·39	0·39	*0·37*	0·36	0·38	0·37	0·37
8½	0·31	0·31	0·31	0·35	0·34	*0·32*	0·31	0·34	0·32	0·32
Averages ..	0·37	0·40	0·39	0·40	0·40	*0·39*	0·38	0·40	0·39	0·39
(*b*) *Potash content of leaf-tissue (per cent* K_2O *in oven-dry material)*										
3	1·66	1·81	1·65	1·74	1·79	*1·72*	1·78	1·67	—	—
4	1·50	1·55	1·61	1·54	1·63	*1·56*	1·53	1·60	—	—
5	1·62	1·74	1·59	1·57	1·55	*1·61*	1·58	1·66	—	—
6	1·38	1·51	1·49	1·43	1·46	*1·46*	1·43	1·48	—	—
7	1·42	1·48	1·39	1·46	1·47	*1·44*	1·43	1·45	—	—
8½	1·38	1·43	1·37	1·37	1·39	*1·39*	1·37	1·41	—	—
Averages ..	1·48	1·59	1·52	1·52	1·55	*1·53*	1·52	1·55	—	—
(*c*) *Nitrogen content of leaf-tissue (per cent* N *in oven-dry material)*										
3	2·50	2·64	2·41	2·53	2·56	*2·53*	—	—	—	—
4	1·95	2·05	1·90	2·01	1·91	*1·96*	—	—	—	—
5	1·64	1·73	1·67	1·74	1·65	*1·69*	—	—	—	—
6	1·60	1·60	1·61	1·63	1·60	*1·61*	—	—	—	—
7	1·43	1·40	1·49	1·70	1·43	*1·49*	—	—	—	—
Averages ..	1·82	1·88	1·82	1·92	1·83	*1·86*	—	—	—	—

out and the remaining laminae were oven-dried. Nitrogen, phosphate and potash were determined on the liquid obtained by wet digestion of 500 mg samples. The results obtained are set out in *Table 2* (*a*), (*b*) and (*c*).

Reaping and Milling the Cane

The stems were fully trashed and the stools cut off at seed piece level. The whole stool was weighed, the 'cabbage' part (cane top) cut off, and the remaining 'millable cane' was weighed. The yield data obtained are given in *Table 3*. Since each set of data gave identical results on statistical analysis, only the 'millable' cane figures are presented, analysed and discussed.

Table 3. Data for Weight of Millable Cane (Kilograms)

Treatments	*Duplicates* Block 1	*Duplicates* Block 2	*Totals*
0	24·75	28·00	52·75
0t	29·50	26·75	56·25
0L	32·75	34·25	67·00
0Lt	29·25	33·25	62·50
1	29·75	31·25	61·00
1t	25·25	30·50	55·75
1L	29·50	34·50	64·00
1Lt	31·75	33·25	65·00
2	30·75	31·75	62·50
2t	26·00	30·25	56·25
2L	32·25	31·75	64·00
2Lt	30·00	31·00	61·00
3	47·25	34·00	81·25
3t	26·75	32·00	58·75
3L	28·00	37·75	65·75
3Lt	31·25	28·50	59·75
4	31·25	30·25	61·50
4t	24·50	29·25	53·75
4L	35·25	33·50	68·75
4Lt	37·00	34·00	71·00
Blocks totals ..	612·75	635·75	*1248·50*

Three-way Table

	Phosphate treatments P0	P1	P2	P3	P4	*Total* (%)
L0	109·00	116·75	118·75	140·00	115·25	599·75=100
L1	129·50	129·00	125·00	125·00	139·75	648·75=108
	238·50	245·75	243·75	265·50	255·00	*1248·50*
M	119·75	125·00	126·50	147·00	130·25	648·50=100
Mt	118·75	120·75	117·25	118·50	124·75	600·00=92½

Statistical Analysis

	D.F.	MS.	F.	
Blocks	1	13·2	—	—
Phosphate (P)	4	14·2	—	—
Lime (L)	1	60·0	6·2*	—
Methods (M)	1	58·8	6·1*	—
P × L	4	29·4	3·05*	—
P × M	4	15·0	—	—
M × L	1	19·6	2·04	—
P × M × L	4	18·1	1·88	—
Error	19	9·63	—	—

* P=0·05

Each of the 40 cane samples was separately crushed in a 3-roller laboratory mill of roller dimensions 14 in. long by 9½ in. diameter. The juice samples were analysed for 'degree Brix', 'pol per cent' and 'purity'. The results obtained are given in *Tables 4* and *5*.

Table 4. Composition of Cane Juice (pol per cent in extracted juice)

Treatments	*Block* 1	*Block* 2	*Totals*
0	16·0	16·2	32·2
0t	15·3	15·8	31·1
0L	17·0	16·4	33·4
0Lt	17·4	16·1	33·5
1	15·7	16·4	32·1
1t	16·7	15·5	32·2
1L	16·9	15·5	32·4
1Lt	17·2	15·7	32·9
2	15·1	15·9	31·0
2t	16·6	16·0	32·6
2L	16·5	16·6	33·1
2Lt	17·6	17·4	35·0
3	14·6	13·4	28·0
3t	17·4	16·3	33·7
3L	17·1	16·5	33·6
3Lt	16·3	16·6	32·9
4	16·0	16·4	32·4
4t	16·0	16·1	32·1
4L	16·9	15·7	32·6
4Lt	16·2	16·2	32·4
	328·5	320·7	649·2

Total phosphate was determined in the filtered, dried and ashed juice samples. The results are given in *Table 6*.

Additional Tests

The bagasse obtained in the milling of six of the treatments, namely, 0, 0L, 3, 3L, 4, 4L, each in duplicate, was analysed for moisture content and ' pol per cent ', so as to furnish data for fibre content of cane and per cent sugar extraction.

Calcium and magnesium were determined on the juice samples corresponding to these samples of bagasse, by the versenate titration method, as described by Honig (1952). Total juice ash was determined by concentration and incineration of the juice samples at 550°C. The results obtained are given in *Table 7*. Finally, a routine ' degree of clarification ' test was applied to the juice samples.

Soil Phosphate

The phosphate status of the soil for each of the phosphate treatments was determined by the Truog method a few days after the fertilizer solution had been added. The results are given in *Table 8*.

Table 5. Composition of Cane Juice (lb. pol in extracted juice)

Treatments	*Block* 1	*Block* 2	*Totals*
0	2·6	2·9	5·5
0t	2·9	2·8	5·7
0L	3·7	3·7	7·4
0Lt	3·2	3·4	6·6
1	3·0	3·1	6·1
1t	2·6	3·1	5·7
1L	3·2	3·6	6·8
1Lt	3·7	3·5	7·2
2	2·9	3·3	6·2
2t	2·7	3·0	5·7
2L	3·4	3·2	6·6
2Lt	3·3	3·6	6·9
3	4·2	2·9	7·1
3t	3·0	3·2	6·2
3L	3·0	4·0	7·0
3Lt	3·3	3·0	6·3
4	3·3	3·1	6·4
4t	2·5	3·0	5·5
4L	3·9	3·4	7·3
4Lt	3·7	3·5	7·2
	64·1	65·3	129·4

CONCLUSIONS FROM EXPERIMENTAL DATA

The Phosphate Status of the Soil (Table 8)

Judging by the contents of available (Truog) phosphate of the phosphated soils (*Table 8*), not only are considerable amounts of phosphate ' fixed ' by this soil, but the presence of free calcium carbonate in them has increased considerably the degree of absorption. The measurement of degree of phosphate ' fixation ' by means of a somewhat arbitrary chemical test should not, however, be accepted unreservedly as a measure of physiological availability of soil phosphate to the sugar cane plant. According to the provisional standards in vogue at I.C.T.A. for available phosphate contents, a value of 24 p.p.m. (Truog) would be regarded as ' medium-low ', and near the limit of adequacy (25 p.p.m.) accepted for sugar cane growing in sandy or loamy soils. (This value for adequacy corresponds closely with the value 0·0025 per cent P_2O_5 in one per cent citric acid extract accepted in Hawaii (McGeorge, 1923).

Increasing responses have been obtained in the field with this soil-type from dressings ranging up to an equivalent of 300 p.p.m. P_2O_5 on weight of soil in the upper 6 in. layer, which fully justifies the inclusion of the higher dosages of phosphate fertilizer applied in this drum experiment.

Table 6. Composition of Cane Juice

(*a*) *Total phosphate in extracted juice* (P_2O_5: p.p.m.)

Treatments	*Block* 1	*Block* 2	*Means*
0	125	123	124
0t	138	128	133
0L	268	220	244
0Lt	255	255	255
1	170	170	170
1t	145	135	140
1L	365	265	315
1Lt	365	250	308
2	135	195	165
2t	170	180	175
2L	300	298	299
2Lt	360	325	342
3	118	175	146
3t	205	155	180
3L	315	275	295
3Lt	300	375	337
4	180	235	207
4t	188	225	207
4L	335	385	360
4Lt	220	350	285

(*b*) *Three-way Table*

Lime	*Phosphate treatments*						
	P0	P1	P2	P3	P4	*Mean*	*Index* (per cent)
L0	128	155	170	163	207	165 =	100
L1	250	311	320	316	322	304 =	184
Means	184	233	245	240	265		
Index	100	121	133	130	144 (per cent)		

Growth measurements (*Table 1 and Diagram*)

The development of the canes in this experiment was evidently quite regular, except that a slight impairment in growth was caused by extreme dry weather during the fifth month, in spite of the watering. Most of the late shoots died at that time, though probably mainly because of over-shading rather than through lack of water and nutrients.

Tiller counts diminished from a mean of 26½ to 15 tillers per drum during the fifth and sixth months, and remained at the lower figure for the rest of the time.

Table 7. Inorganic Constituents in Expressed Juice

Treatments	Averages of Blocks 1 and 2		
	CaO (p.p.m.)	MgO (p.p.m.)	Carbonated ash (per cent)
0	366	388	2·95
0L	509	407	3·73
3	464	439	3·18
3L	513	431	3·73
4	364	388	2·95
4L	454	374	3·70
Mean L0 ..	396	405	3·02
Mean L1 ..	492	404	3·72

Table 8. Phosphate Recovery in Soil

Treatments	Phosphate added per drum	Phosphate added to soil		Available phosphate recovered		Phosphate chemically 'fixed' by soil	
	(g. P_2O_5)	150 kg. (p.p.m. P_2O_5)	50 kg. (p.p.m. P_2O_5)	Unlimed series (p.p.m. P_2O_5)	Limed series (p.p.m. P_2O_5)	Unlimed series (per cent)	Limed series (per cent)
P0	0	—	—	24	24	—	—
P1	3·75	25	—	30	28	76	84
P2	7·50	50	—	38	32	72	84
P1	3·75	—	75	47	36	69	84
P3	15·00	100	—	57	42	67	82
P2	7·50	—	150	76	51	65	82
P4	30·00	200	—	95	65	64	78
P3	15·00	—	300	133	96	63	76
P4	30·00	—	600	±250	—	62	—

Total stem lengths were nearly the same for all treatments. Index figures computed for treatments for the whole of the growth period were nearly identical with those calculated from the last measurement only. This implies that the treatment responses were constant throughout the whole growth period. The only significant growth-in-length response was given by the P3 treatment whose effect seems to have been outstanding.

Leaf Analysis (Table 2 a, b and c)

Phosphate Uptake—The levels of phosphate in the leaf tissue show a definite decline in phosphate uptake with increasing age. The mean value at three months of 0·50 p.p.m. falls to a mean value at reaping time of 0·32 p.p.m., a fall of 36 per cent magnitude. The different phosphate treatments (P1, P2, P3, P4) all caused nearly the same amount of phosphate uptake as compared with no treatment (P0). This suggests that they were excessive or super-optimal, whereas the P0 level evidently was nearly inadequate, or almost sub-optimal.

Differences in effect between the phosphate treatments were greatest at the younger ages, probably because of the restricted root development at those times.

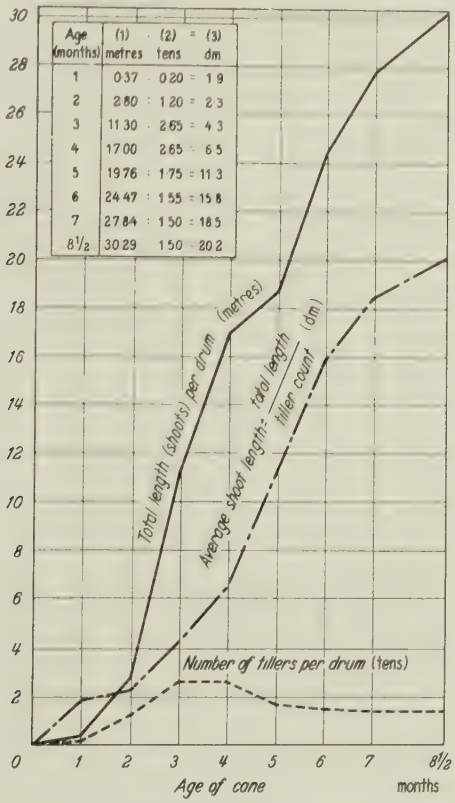

Figure 1. Experimental growth measurements

The levels of phosphate were slightly but consistently higher for the limed soils than for the unlimed soils, but the two different methods of phosphate fertilizer placement did not produce any differences in phosphate uptake.

Nitrogen and Potash uptake—The levels of both nitrogen and potash in the leaf-tissue showed a decline with age but were still maintained within the 'limits of optimum supply' as gauged by Mauritian standards which are : 1·66 to 1·85 for nitrogen (N) and 1·26 to 1·75 for potash (K_2O). The level of nitrogen fell to the incipient deficiency level during the seventh month period, even though a dressing of ammonium sulphate was given in the sixth month.

Yield of Sugar Cane and of its Components (Tables 3, 4, 5, 6a and 6b)

Weight of Millable Cane—The data in *Table 3* demonstrate that the yield response of sugar cane, in terms of weight of millable cane, to phosphate in this experiment is practically *nil*. There is a significant response, however, to lime of about 8 per cent. There is also a significant depressing effect of placing all the phosphate in the topsoil of about 7·5 per cent. This effect is

not influenced significantly by lime, though a tendency is shown for lime to lessen the depression. Finally, there is a significant interaction between phosphate and lime. In the absence of lime, an increase of 7 per cent is given by the first phosphate treatment (P1) over no treatment (P0). The P3 treatment shows a sudden and larger yield increase, but this is not significant. The fact that the higher dosages of phosphate do not produce corresponding increases in yield is in accordance with the results of leaf analysis.

Cane Quality—This may be gauged by sugar content of cane which may be deduced by applying the formula,

$$\text{Pol per cent cane} = \text{Pol per cent juice} \times \frac{\text{lb. juice} \times 100}{\text{lb. cane} \times \text{Pol extraction}}$$

The ' Pol extraction ' values derived from the milling test applied to samples representing six selected treatments vary within narrow limits (80 to 82) and may be regarded as constant. Further, the ratio, lb. juice to lb. cane, for the different treatments did not show any significant differences and therefore also may be regarded as constant. Thus, the percentage of sugar in cane in this experiment may be assessed by ' Pol per cent juice ', as given in *Table 4*. Statistical analysis of the data demonstrates that there is no significant response of this factor to any of the treatments, or, in other words, no effect on ' quality ' of cane.

Quantity of Sugar—Since ' Pol extraction ' may be taken as constant, ' lb. Pol in juice ' may be accepted as a relative measure of the quantity of sugar produced by the cane. Statistical analysis of the data for this factor given in *Table 5*, shows that only the lime treatment has affected sugar yield and that this effect is highly significant. The mean yield for the different treatments is 3·01 lb. ' Pol in juice ' for the no-lime treatment (L0) and 3·44 lb. for the lime treatment (L1), showing an increase in the total sugar produced of more than 10 per cent.

' *Available Sugar* '—Purity of extracted juice is an important attribute from the factory operator's standpoint, because the higher the degree of purity, the larger the amount of sugar that can be extracted and bagged. In this experiment the purities of the different juices show such small variation that statistical analysis of the data for purity was not attempted. The lime treatment showed a definite but small benefit, the purity being 89·3 against 87·4 for the no-lime treatment.

Total Phosphate in Juice—A 44 per cent increase in total phosphate content of juice is indicated by the data in *Tables 6a* and *6b* for phosphate treatments, namely, 265 p.p.m. P_2O_5 in the juice from the P0 treatment as compared with 184 p.p.m. P_2O_5 from the P0 treatment. The effect of liming in increasing the phosphate content of the juice was evidently very large, amounting to an average increase of 84 per cent in total phosphate content of juice. This result is important in relation to juice clarification discussed below.

Additional tests (*Tables 6b, 7*)

Fibre in Cane—The mean fibre content was 14 per cent, but the variation between duplicates of the samples from six selected treatments was so large that the differential results obtained cannot be regarded as significant.

Clarification of Juice—The efficacy of the clarification process was gauged

by appearance and colour. One litre portions of juice from the six selected treatments were limed to pH 8·0, heated to boiling, and settled in tubes kept near boiling temperature. Large differences were noted. Juices from no-lime treatments were turbid and dark coloured, whereas juices from limed treatments would have been described as ' good ' in the commercial factory. For satisfactory clarification, a juice should contain a minimum concentration of phosphate, which, for the juices in question, should be about 200 p.p.m. P_2O_5 of juice. The data in *Table 6b* show that this standard was attained by the L0–P4 combination, as well as the L1–P0 combination.

Inorganic Juice Components—The data in *Table 7* show that the lime treatment increased the amount of calcium and of total ash in the juice. Magnesium contents remained rather constant, though at the high level of about 400 p.p.m. MgO because of the rather large dressing of magnesium sulphate added to the drum cultures.

GENERAL DISCUSSION

Examination of the root systems of the sugar cane plants at the end of the experiment provided convincing evidence that the full volume of the soil had not been completely occupied by the cane roots, although prolific ramification within the coarsely-aggregated and well-aerated soil had evidently taken place. This evidence combined with the information obtained from growth measurements, leaf analysis and yields of sugar cane, indicates that the soil used in this experiment contains nearly sufficient ' available ' phosphate to support a cane crop. A dressing of only 0·75 cwt. per acre of ' double ' superphosphate (containing 40 per cent P_2O_5) increased the yield by about 7 per cent, and the phosphate level in the leaf tissue was slightly raised thereby. Larger dosages of phosphate fertilizer gave no further response. In the absence of lime, the lowest phosphate dosage raised the available phosphate content (Truog value) of the soil from 24 to 30 p.p.m. P_2O_5. A similar effect to that obtained by the addition of phosphate was also obtained with this highly acid soil by simple liming. This result is attributed to the stimulation or improvement of the root system of the cane plant by liming, whereby it is able more fully to utilize the phosphate resources of the soil. It has been noticed that, in the absence of lime, the root tips, both of sugar cane and of other test plants, such as Sudan Grass and Maize are severely damaged by this highly acid soil, possibly through the toxic effect of free aluminium-ion. Such damage (which takes the form of ' club-tip ') does not affect the roots after the soil has been thoroughly limed. Under this influence, the phosphate content of the cane juice is almost doubled and the efficiency of the factory clarification process is greatly enhanced. Liming also increased by about 10 per cent the total sugar produced by the cane.

In judging the requirements of this highly acid soil for improved sugar cane production, it would appear that the chief and only real need is lime. Nevertheless, a small but significant response to phosphate was obtained in the absence of lime, and it is noteworthy that quite large responses to phosphate were also obtained in previous pot tests with other, but smaller, indicator plants, namely Sudan Grass and Maize (*see* Paper III). In another application of Type 3 kind of pot test, to be described in a future

article, in which 4 gal. kerosene tins were used for testing the same highly acid soil with sugar cane, employing exactly the same method of filling, fertilizing and planting as in the case of this drum experiment, yield responses from the three-month old cane gave yield increments of 38 per cent, 57 per cent and 70 per cent for the phosphate dosages P1, P2, P3 respectively. In these instances, a limited volume of soil available to the root system accentuates the low level of phosphate in the soil.

This suggests that, if the physiological efficiency of a root system is impeded, either by adverse physical soil conditions, such as high acidity or lack of oxygen, or by restricted rooting volume of the soil, the supply of available phosphate per unit of soil is no longer adequate to meet the requirements of the plant. In these instances, a higher phosphate content of the soil has to make up for lower efficiency of the roots. Likewise, with prolonged ratooning, additional but relatively small dressings of phosphate may be needed to maintain the phosphate level of the soil above that needed for the satisfactory nutrition of the plant.

SUMMARY

(1) An experiment is described in which sugar cane was grown in 40 gal. oil-drums to age of eight and a half months, providing an example of a Type 2 pot test mentioned in Paper I of this series. The soil was highly acid and phosphate-deficient, belonging to the same soil-type as that used in pot tests with Sudan Grass and Maize, described in Paper III.

(2) The treatments whose effects were to be traced were (*a*) single-dose high liming, and (*b*) five levels of phosphate fertilizer, either (*i*) dispersed throughout the whole soil or (*ii*) ' placed ' in the surface layer only.

(3) Measurements were made at intervals of stem length, and the number of tillers was counted. Leaf samples were periodically analysed and final yields were determined. Juice samples were also analysed at the time of reaping and clarification tests were applied to them.

(4) The data obtained demonstrate that a considerable amount of information may be obtained in a relatively short time by a pot test of this kind, in regard to the responses likely to be obtained with lime and phosphate fertilizer of any particular soil that is to be used for growing sugar cane commercially. This is only possible, however, if the container is large enough and the degree and stability of aggregation and the mode of packing of the soil suitable for the maintenance throughout the experimental period of adequate aeration and free water movement which are necessary for prolific root development.

ACKNOWLEDGMENTS

The authors wish to thank Prof. F. Hardy for help in the compilation of this article, and Dr. A. L. Jolly for advice regarding the analysis of data. They also wish to express their indebtedness to the Management of the Government Experiment Station at Centeno, Trinidad, for providing the soil used in the experiment.

(*Received February 1954*)

REFERENCES

Honig, P. (1952). *West Indies Sugar Corporation.* Report No. 2

Schroo, H. (1953). *Trop. Agriculture, Trin.*, **30**, Nos. 10–12, Paper I, 199–205 ; Paper II, *ibid.* 206–215 ; Paper III, *ibid.* **31**, 71–78

Book Reviews

THE AFRICAN VETERINARY HANDBOOK

P. Z. Mackenzie and R. M. Simpson. Sir Isaac Pitman & Sons Ltd., Nairobi, 1953. 260 *pp.* 15*s*

This volume describes, in terms which a layman can understand, the principal diseases with which the stockowner in Africa has to contend, but though specifically designed for use in Africa, it will have a wider appeal. Many of the diseases described are, unfortunately, all too prevalent throughout the tropics and thus the farmer, the stockman and the student, not only in Africa but in other parts of the tropical world, will find in this reference book much material that will be of value to him.

The authors have compressed into some 260 pages an account of 130 diseases of domestic stock ; for this reason it has not been possible to deal with each disease in any great detail, nevertheless the descriptions given of symptoms, causes, diagnostic aids and treatments are clearly, if briefly, recorded.

In addition to the chapters dealing with specific diseases, there is a concise introductory section which will provide the lay reader with the necessary background for the further use of the text, and in addition there is included a chapter on internal and external parasites, and sections which deal with such miscellaneous subjects as artificial insemination, breeding, caponization, castration, poisons, dipping, first aid and other problems associated with tropical livestock management.

By the use of an excellent format and clear factual exposition the authors have produced a readable and valuable handbook which will be of use to all those whose work brings them into contact with tropical livestock.—A.B.K.

EASTERN AND WESTERN WORLD

W. Van Hoeve Ltd., The Hague, Netherlands. 181 *pp.* 15*s*

This book contains selected readings from summer semesters held in the ancient University of Leyden in 1951 and 1952. There are 11 papers in all ranging from political relations between East and West to the population increase. As with any similar selection the subject matter is very varied and this feature indicates the main utility of the book. For anyone in underdeveloped countries, working in whatever sphere, the selections provide entertainment and at the same time mentally salutary reading. How often, for instance, do we remember in the humdrum of daily work that western civilization is the upstart in the world; that more ancient communal organizations developed centuries ago to fit conditions that a westerner today can hardly visualize.

The book is well produced and the English translation generally clear. It is recommended as home reading for all workers in the more remote corners of the world.—A.L.J.

THE PAPUA AND NEW GUINEA AGRICULTURAL GAZETTE

Vol. 8, 1953–4. Annual subscription 6*s*, or 1*s* 6*d* per quarterly number; from The Editor, Department of Agriculture, Stock and Fisheries, Port Moresby

This first volume of the new series of the *Papua and New Guinea Agricultural Gazette* is a resumption of the *New Guinea Agricultural Gazette*, whose publication ceased during the war. It contains in the first number articles of interest on vegetative propagation of cacao and diseases of coconuts in the territory, a comparative survey of the rice industry in British Guiana, and shorter notes on many other subjects. The standard of contributions makes it a welcome re-entrant among publications on tropical agriculture.

An editorial note describes the organization and staffing of the Department of Agriculture, Stock and Fisheries. Agricultural officers in Colonial Office territories may regard with envy an establishment of 172 expatriates and over 2,000 native personnel; but in relation to a combined area for the two territories of 183,540 square miles they will agree that it is not too lavish. The time is ripe for New Guinea to take the place among tropical agricultural producers which is hers by right of size; and publication of this Gazette will help her to do so.—G.B.M.

FOOD AND HEALTH

S. D. Onabamiro. Penguin West African Series, 1953. 124 *pp.* 1*s* 6*d*

This little book is welcome on three counts: because it covers an important subject, because it is written by a qualified African scientist, and because the series of which it is an early member represents an exciting new venture in publishing for the tropics. The science of human nutrition is one that is of interest to all concerned with agriculture. Dr. Onabamiro has succeeded in writing at just the right scientific level for the educated classes in West Africa. May we hope that Penguin Books Ltd. will be moved before too long to add to the series an equally cheap book on agriculture, the basic industry of West Africa ?—G.B.M.

EGYPTIAN COTTON

C. H. Brown. Leonard Hill Ltd., London, 1953. 174 *pp.* (illus.) 16*s*

The author of this book spent 30 years working in the Botanical Section of the Egyptian Ministry of Agriculture, and in his book Mr. Brown tells the story of the growth and development of the cotton crop in Egypt against the background of the Egyptian agricultural scene.

The first chapter gives a brief account of such fundamental matters as irrigation, agricultural rotations, land tenure and the place of cotton in Egyptian Agriculture, this is followed by sections dealing with the gradual development of the cotton crop during the past 50 years and details are given of the system of growing and harvesting the crop. Following a chapter on diseases and pests, we come to the most important sections of the book, namely those chapters which deal with the breeding, testing, bulking and distribution of new varieties. The volume closes with short chapters on the economics of the industry and with references to Egyptian cotton in other countries.

To one who has been concerned with cotton improvement work the main chapters of the book are most interesting since they deal in detail with problems which are common to all cotton-growing countries and the work which has been done in Egypt and the results obtained, which are fully described in the appropriate sections, must be a source of great satisfaction to the author and to his colleagues. The main criticism of the reviewer is that the mechanics and methods of selection, breeding and testing, multiplication and distribution of new varieties, interesting though they are, have been dealt with in such detail as to relegate to the background other important aspects of the subject which have been but briefly dealt with.

In the chapter on the breeding of new varieties the author brings out points of interest when he deals with the problem which to the cotton breeder is ever present, namely the often conflicting merits of a new variety when regarded from the agriculturist's or from the spinner's view-point and the understood difficulty frequently experienced of getting spinners to accept a cotton which is markedly agriculturally superior but which, to the spinner, represents a quality to a degree different from that to which he has been accustomed.

The book provides ample evidence of the success which has been achieved in Egypt in the improvement of the range of Egyptian cottons, and it emphasizes the value, when dealing with a crop such as cotton, of a continuous long term and sustained breeding policy. It is a book which should be read by all who are in any way concerned with the commercial production of cotton.—A.B.K.

Recent Publications of The Imperial College of Tropical Agriculture

Studies in West Indian Soils, XII: The Agricultural and Forest Soils of St. Lucia, by F. HARDY and G. RODRIGUES. 5*s*

Studies in West Indian Soils, XIII: The Agricultural Soils of St. Kitts-Nevis with Notes on Statia (Dutch), by F. HARDY and G. RODRIGUES. 5*s*

A Report on Cacao Research, 1945–1951. 132 *pp.* fully illustrated in colour and black and white. 25*s*

A Report on Cacao Research, 1952. 8*s*

These and other publications can be obtained from the Library and Publications Department, Imperial College of Tropical Agriculture, Trinidad.

Editorial

To the regret of the Governing Body of the College, Sir Raymond Priestley felt obliged to resign its chairmanship at the end of 1953. He had been in poor health for some time, and in accepting a prolongation of his term earlier in the year had let it be known that he would not be able to continue beyond the end of the year. Sir Raymond's distinguished scientific career began as geologist to the Shackleton Antarctic Expedition 1907–9 and culminated in the Principalship and Vice-Chancellorship of the University of Birmingham. He had been a member of the College's Academic Committee since 1947, and was co-opted to the Governing Body in 1949. The College must be grateful for having had a scientist and university administrator of such experience to preside over its recent counsels. Sir Raymond's chairmanship coincided with a difficult financial period when inflationary tendencies made budgeting difficult for any institution; but he has the satisfaction of handing over to his successor with the College strengthened in buildings and staff, and financial stability achieved.

Sir Frank Engledow, who succeeds Sir Raymond, needs no introduction to readers of this journal. Most former Colonial Office students at the College have known him personally in his capacity as Drapers' Professor of Agriculture at Cambridge. He has a long and first-hand experience of tropical as well as temperate agriculture, and obtained a wide knowledge of the West Indies as a member of the 1938–9 Royal Commission. Neither is he any stranger to College affairs, having paid his first visit to the College in 1929 and served on its Governing Body as the representative of Cambridge University from 1929 to 1949. Amongst many other activities he is a member of the Agricultural Improvement Council of England and Wales, Chairman of the Food Investigation Board of the Department of Scientific and Industrial Research, and President of the British Food Manufacturing Industries Research Association.

The College is indeed fortunate in those who are willing to give of their valuable time to direct its policy.

Progress in the Mechanization of Farming in the Colonial Territories

A Visit to Central Africa, East Africa and the High Commission Territories

J. E. Mayne

Colonial Agricultural Machinery Advisory Committee, Colonial Office, London

Mechanization in agriculture, like industrial mechanization, is a facet of the broader field of economics. ' Agricultural mechanization ' should not be confused with ' agricultural engineering '. The former is concerned with the application and management of machines in commercial crop or livestock production; while the latter embraces special aspects of the sciences and skills of mechanical, civil and electrical engineering used in designing and constructing machines, buildings or field works.

In earlier papers, the writer has drawn attention to the suggestion that ' economic ' mechanization must depend upon the use of standard or near-standard quantity-produced equipment. Cheapness, standardization and versatility are important qualities in machines for general use in tropical farming. Only in very unusual circumstances can strictly local requirements be met with machinery which is sufficiently cheap, versatile and supported by spare parts and service facilities.

The present paper describes, therefore, some of the progress which has been made in introducing modern mass-produced machinery into tropical farming, in several British territories in Africa.

BACKGROUND

The conditions under which agricultural machines are required to work in eastern Africa vary from saturated soils at sea level to wide open cereal-growing uplands at 10,000 ft. elevation. This represents a wide range of climatic and atmospheric conditions in addition to the usual variety of agricultural soils, crops and methods. A tractor's performance—like a man's—falls off at high altitudes.

There are probably fewer than 20,000 tractors at work in all the British colonial territories, and recent imports of agricultural tractors and machinery into the colonies are shown below:

	£
1938	379,000
1947	3,187,000
1949	7,305,000
1950	5,274,000

The reduced expenditure in 1950 is largely due to reduced imports into East Africa, probably owing to the combined effects of stiffening currency control (limiting dollar expenditure) and a fall in purchases for the Groundnuts Scheme. The equivalent figure for total world imports of agricultural machinery during 1950 is £225,000,000. It is interesting to note in passing

that in 1947 East Africa bought £403,000 worth of equipment from the United Kingdom and £1½ million from the United States; while in 1950 approximately £1½ million worth was bought from each source.

Post-war experience has indicated that a major problem facing many mechanized agricultural projects in the tropics is the shortage of really first class, trained and experienced staff at all levels from machine operators up to project managers. The difficulty has been aggravated by the fact that it has only been possible to develop training facilities along with the establishment of the early projects instead of in advance of them. At a higher level, the National Diploma in Agricultural Engineering and the M.Sc. degree have only become available in recent years.

THE TOUR

During February–May, 1953, the writer undertook a fact-finding tour of eastern Africa, under the auspices of the Colonial Agricultural Machinery Advisory Committee, and with the very helpful co-operation of the territorial governments. The itinerary included Northern Rhodesia, Swaziland, Basutoland, (Salisbury, Southern Rhodesia), Nyasaland, Tanganyika, Zanzibar, Kenya and Uganda. A mass of information was collected (much of the detail concerning the mechanical performances of machines) from which the following general conclusions were drawn:

(*a*) There was little evidence of an immediate and general need for serious modification of existing machines, or the design of completely new types of machine; certain important exceptions were recognized.

(*b*) There was scope for the further development of British-made machinery for weed control, maize growing, and certain disc cultivations.

(*c*) The products of *certain* outstanding American manufacturers were less subject to breakage in rugged conditions than machines of other origin; poor service from some manufacturers' agents made breakage a more serious fault.

(*d*) In the planning of many mechanization schemes in African areas the cost of mechanical operations had been under-estimated and machine performance had been over-estimated. There was a lack of basic data necessary for planning co-ordinated experiments in mechanization.

(*e*) Facilities for testing machinery in the colonies, without at the same time impeding the excellent progress which was already being made, were urgently needed.

(*f*) The territorial departments of agriculture were very much alive to the implications and possibilities of mechanization. Excellent progress was being made, often against very considerable difficulties and in spite of staff shortages. Many departments had developed mechanization to a high degree of efficiency, especially in soil conservation services, mechanized food farms, and contracting services.

COST OF MACHINERY OPERATIONS

In the tropics mechanization is usually very costly owing to high rates of depreciation, breakage, and to the expense of repairs. Unfortunately, although many records have been kept, very few cost analyses have been published. The main function of agricultural tractors in the colonies

today is to plough the land and prepare it for planting, ' timeliness ' often being the objective; and even peasant farmers may be prepared to pay high charges in order to get the land turned over at the right time. Other operations, however—probably being less urgent—may well be more economically undertaken by human or animal labour.

It is important to consider ways and means of reducing the cost of tractor operations so that (*a*) mechanization may become attractive in many laborious and, possibly, inefficient operations, and (*b*) by spreading tractor work over as wide a series of operations as possible, long working ' years ' may be achieved and the cost per hour reduced.

In the present paper, it is not proposed to discuss large-scale ' projects ' in which overheads and operating expenses have been spread over thousands of acres laid out especially for mechanization, but to concentrate on the running costs of tractors as experienced by individual farmers, agricultural stations and contract units. Such tractors may be used for only 400 to 800 hrs. out of a possible 1,500 to 1,800 hrs. per year.

Tractor Running Costs—First, capital costs are relatively high, because to the factory price of all equipment must be added packing, freight at sea (and, probably, on rail), dock and handling charges, and agents' commissions which may amount to 33⅓ per cent. Second, the cost of replacement parts is high for the same reasons; furthermore, parts may at times attain a special scarcity value in spite of official price control regulations. Third, fuel may be expensive both in cost, and to handle. Fourth, in some areas, the replacement of tyres may become extremely expensive; and fifth, rough handling of equipment in rugged conditions may cause exceptional wear and tear.

Examination of the following figures indicates that expenditure on fuel, lubricants and wages is relatively low, while the cost of supervision, depreciation, replacements and repairs is high. Although there is undoubtedly room for improvement in the handling of tractors in the colonies, it is also evident that a reduction in the cost of spare parts and services would be extremely beneficial to tractor users in the colonies.

Analysis of the Cost of Operating a ' Typical ' 40 b.h.p. Diesel Wheeled Tractor in East Africa, Mainly for Heavy Cultivations on Hard Land Containing Rocks and some Stumps (Composite figures)

	Shillings per year
Share of overheads (includes garage, workshops mechanic, field assistant or foreman, and European supervision) ...	6100·00
Depreciation (Cost of tractor, £700; life 7 years)	2000·00
Interest on capital investment (3 per cent of ' average ' value)	210·00
Fuel : 896 gals @ 1*s.* 6*d.*	1344·00
Oil and grease, *etc*	700·00
Spare parts (including tyres)	3270·00
Share of major overhaul done in machinery dealer's workshop (£105–7)	300·00
Wages (1 driver, 1 boy)	2234·00
Total ...	16158·00

Hours worked during year: 736. *Cost per hour* 22*s.*

Cost of Field Operations—A review of the charges made by Government-sponsored hire schemes in several African colonial territories shows that 40*s*. per acre is about the lowest possible 'economic' fee for ploughing peasant land. In several ploughing schemes the actual cost is considerably higher than 40*s*., and may be as high as 90*s*., especially when the full costs of supervision and travelling expenses are included. On the other hand, in one of the more successful schemes a tractor working within a two mile radius of its centre can cultivate 150 acres per season, the full cost of the sequence of operations involved in breaking land out of grass fallow and preparing it for planting being about 60*s*. Certain factors which contribute to high costs are inherent in contract schemes and include travelling time, supervision, the inclination of the farmer to leave the worst land to the contractor, and, possibly, his reluctance to state his requirements early in the season. Experience shows that it is not unreasonable to assume that 25 to 30 per cent of the tractors in any scheme are likely to be out of action at any one time owing to breakdown or shortage of spare parts, and this adds a considerable burden to all-in costings.

MANUFACTURERS' AGENTS

In most of the territories visited dissatisfaction was expressed with the after-sales service provided by manufacturers' agents, and in particular about the cost—and inadequate stocks—of spare parts. The agents may have a critical part to play in the further general development of mechanization and it is reasonable that their performance should be reviewed briefly.

First, it must be recognized that they face many problems, including:

(*a*) *The difficulty of obtaining a wide range* of equipment suitable for the local market from one maker.

(*b*) *Some dollar-area manufacturers* were very early in the field, and helped to build up many of the agencies from small beginnings; these established agencies may also carry many sterling-area products (*e.g.* stationary engines, milking machines, barnyard machinery) the sale of which used to be helped by the original dollar products which are now very difficult to import owing to currency restrictions.

(*c*) *Shipping* from Europe is still slow, and the agents may be unable to satisfy local requirements; and agricultural machinery as a whole cannot gain priority in shipment.

(*d*) *United Kingdom prices* remain high; it is anticipated that an American combine-harvester now being made in Britain will cost £200 more than the American version.

(*e*) *An incidental, but unfortunate, effect of the control of dollar expenditure* is that in some territories the longer-established firms (bound morally and, presumably, by agreements to their American principals) do relatively less business, and the inexperienced firms do relatively more. This may result in less overall expansion, and less service to the farmers. One of the leading firms in Nairobi employs 75 European technicians and runs a fleet of 35 service trucks.

(*f*) *Volume of business.* One well-known company in East Africa has pointed out that no agency could exist only on the present volume of trade in agricultural machinery; and it is unlikely that the future will

bring any remarkable increase because the market amounts to 2,350 farmers spread over hundreds of miles with conditions more varied than exist in Hampshire, Cambridge and Argyll, and a dearth of local engineering firms capable of helping with the spare parts and service problems. The result is that many agents regard agricultural machinery as one of their less important sidelines.

(*g*) *Short delays in delivery*, as well as shipping, may make equipment late for the onset of a season or for a period of the year during which farmers have ready-cash for investment in implements.

(*h*) *Packing of equipment* in the factory has often been reported as inadequate for shipping, and the breakage rate has caused the importing agents some concern.

On the other hand, some agents appear to be selling machines before testing them adequately and before their salesmen and technicians have become thoroughly experienced in their operation, adjustment, and repair. The reputation of the same manufacturer may be high in one territory and low in another, solely as a result of the efficiency of the different agents. In one or two territories liaison is maintained between the farmers' organization and members of the machinery trade by means of a joint committee, but this does not appear to be common practice.

Spare Parts—Stocks of spares held by many of the agents and sub-agents are very low, this being a reflection of the low volume and slow turn-over of trade in agricultural machinery (although some of the bigger firms are reported to have up to £500,000 worth of stock). An inspection of many store-rooms in farms, projects and agencies led to the conclusion that the best mechanized farms and schemes were successful largely because (*i*) the man in charge had first-hand knowledge of machinery operation, service and maintenance, and (*ii*) the capitalization included a very large stock of spare parts *on the spot* to act as a buffer between field requirements and the agents' stores which might be both deficient and far distant.

TECHNICAL PROGRESS

Paddy Cultivation—Particularly noteworthy developments have taken place in the mechanization of paddy cultivations and harvesting. Large-scale operations have been in progress in British Guiana for more than 10 years, and extensive pilot schemes have been initiated elsewhere, including Tanganyika, Sierra Leone, and Nigeria. Experiments in Malaya have gone far to establish the feasibility of mechanical methods of cultivation under local conditions and particular attention is now being paid to harvesting and threshing. In Surinam two-tractor ' family ' farms have been planned on a basis of 72 hectares, of which 12 to 24 hectares would be in grass. Special attention is being given in Surinam, Malaya, Nigeria and elsewhere to the problems of clearing swamp forest and mangroves; and present indications do not, in general, appear to favour purely mechanical methods—whether considered on an economic or a physical, basis.

On most types of paddy land, other than the deep ' bottomless ' peats, some form of mechanical traction has been achieved. Tractor wheel adhesion has been gained either by the penetration method, which is effective when shallow mud covers a firm sub-soil, or by flotation which

depends upon the use of over-size tyres, drum wheels, cage wheels, or double wheels. Owing to the pushing action of its rotor, the rotary hoe has proved useful on small and medium-sized rice holdings in some areas, notably Siam.

Various other principles of traction have been adopted for trial in connection with wet land cultivations including cable-haulage from the headland, self-winching against an anchor at the headland, and the use of tracklaying tractors fitted with broad tracks; but it seems likely that any widespread acceptance of mechanical traction in rice farming must depend—for reasons set out in earlier paragraphs—upon the use of near-standard, mass-produced, medium sized, wheeled tractors.

Paddy Transplanting—In areas where transplanting, as distinct from seed drilling or broadcasting, is the accepted practice a worker can plant about ¼ acre per day and may, in some Asiatic countries, be paid as little as a shilling. It will be appreciated that mechanical transplanting is likely to be uneconomical where labour is cheap and fields are small. That the process *can* be mechanized is shown by the development in Italy of a machine which has enabled a tractor driver and three assistants to do the work of 60 hand workers. In order to maintain a fast and economic rate of work the machine must constantly be fed with magazines previously charged with plants, and 40 workers are required to gather the plants from the nursery and load the magazines.

A much simpler machine for animal draft, intended for use in Burma, has been described, although the device itself has not yet passed the ' working model ' stage. It is designed to work at about 0·8 m.p.h., the speed of a typical ox, and works on a dibble principle; it could be built locally in hardwood with small imported components, but, by its very nature, it has failed to interest a commercial manufacturer and may never reach the prototype stage.

Paddy Husking—Considerable interest is now being taken in rubber roll type huskers in which the husk is removed as the grain passes between two rubber rolls or belts moving at different speeds. This process results in fewer broken grains than the older more vigorous method, although the rate of wear of the rubber parts is reported to be high. At least five manufacturers in Japan, as well as others in Europe, have undertaken the production of these machines. At present only one British machine of this type is on the market; it is of high capacity, but it is understood that the development of something smaller is under consideration.

Damage to Tractor Tyres—In some areas field conditions are particularly hard on tractor tyres. In the Lake Province of Tanganyika, for example, jagged outcrops of rock are responsible for much damage; in some parts of India trouble has been experienced from bayonet-like stubble of Indian millet and *Euphorbia spp.*; and in many areas thorns and splintered stumps have added to the depredations of the climate. Some of the European farmers in Northern Rhodesia prefer to use tracklayers than to face the delays and rising costs of replacing pneumatic tyres. In some conditions it may be possible to use industrial type tyres which, having deeper shoulders and more tread rubber, present more resistance to sharp bodies. It is also possible that careful attention to the maintenance of correct tyre pressures would reduce the incidence of damage, especially to side walls.

Tie-Ridging—The process of placing frequent cross-ties between adjacent rows in a ridged row-crop appears gradually to have been gaining favour in several tropical colonies, especially as a means of water and soil conservation, while in the U.S.A. it has been in a steady decline, other more fundamental conservation practices having superseded it. In certain circumstances (*e.g.* the Sukumaland ridges, Tanganyika) the value of tie-ridging has been conclusively proven in field experiments; but no machine has yet been especially developed for colonial conditions, although a world-wide manufacturer has demonstrated a machine from California which appears to be adequate for ridges and ties of ' standard ' proportions. Unfortunately, co-ordinated basic data are still lacking as regards optimum and acceptable standards, throughout whole regions, of ridge size, spacing and shape, and of frequency and size of ties. If the benefits of cheap mass production are to be fully realized, a machine of this sort should be of very wide application, and should, ideally, be equally acceptable to growers of maize, cotton and yams.

Brush and Weed Control in Perennial Crops—The control of brush and rank weeds in perennial crops has become a major problem in many areas, especially where the cost of labour has risen sharply. Five mechanical methods have appeared: cultivation by discs, cultivation by rotary hoe, mowing, mechanical slashing, and crushing. Opinions and experimental evidence apparently vary as to the relative merits of cultivation, cover cropping and weed-mulching under different conditions. The off-set tandem disc harrow has been developed over many years for orchard work, and it is now available from Britain, as well as the United States, with or without a seeder mechanism for the planting of cover crops. The leading manufacturers of rotary hoes have been developing a special reduction gearing device which enables a standard tractor fitted with a rotary hoe unit to cultivate the soil to a rough, cloddy tilth, more or less resembling the work done by labourers with ' jembe ' hoes. Although special heavy-duty cutter-bars have been developed by several makers of agricultural mowers, the rough conditions of many tropical plantations do not favour this type of machine. The life of the average cutter-bar in terms of working hours is not very great; although, in a temperate climate where mowing is a strictly seasonal operation, its working life may be extended over several years.

Much greater success has been achieved by two completely different machines both passing under the name of bush (or brush) cutter. For small and medium tractors the cutter consists of a rear mounted blade which rotates in a horizontal plane under a steel cowl. A narrow swath of dense shrub and herbage can be disintegrated by this equipment, the passage of the tractor assisting, to some extent, in pressing down the bush into the arc of the slasher. Heavy tractors have achieved remarkable results with heavy, trailed rollers on which steel ' cutter ' bars are mounted radially, like the beater bars on a threshing drum. For best results two rollers are mounted in tandem, but angled so that the bush is crushed and cut with a combined pressing and shearing action. On land covered predominantly with grasses the roller-cutter breaks up the sod and can be used to stimulate rejuvenation.

Mulch Farming—The growing practice, in the United States and elsewhere, of using crop residues as a surface cover has resulted in the development of machines for cultivation under mulch. It is not suggested that this equipment is directly applicable in all tropical conditions, but recent work in the U.S.A. will be of widespread interest. Various devices have been used to prepare narrow strips of tilth through a mulch for the sowing of row crops, experiments have been made with double cut ploughs which invert the top three inches of the soil and thoroughly cultivate the next four inches. Subsequent cultivations brought about half of the crop residues back to the surface and left the remainder distributed throughout the top three inches of soil. Enthusiastic readers of Faulkner's '*Ploughman's Folly*' will find much comfort in these trials.

Tea—It is difficult to visualize mechanization in existing tea gardens, but the matter is receiving serious consideration. In Ceylon approximately 80 per cent of tea estate labour is devoted to field work and only about 10 per cent to factory processes. It is envisaged that weeding might be mechanized, while further developments could take place in mechanical plucking, general estate services, land clearing and replanting. Far-reaching developments are likely to be possible only if the whole question of bush pattern and field layout is thoroughly reviewed.

Implements for Animal or Manual Power—There has been little startling development in the design of implements for animal or manual operation, but the use of simple equipment of this sort is gradually becoming more widespread in under-developed areas. Peculiar to small implements are the intense local preferences for particular models or types of tool. These are evident not only in field tools (*e.g.* long or short handled hoes, machetes, grass-knives or scythes), but also in processing machines (*e.g.* bench-fitting, one-man mealie grinder versus two-man grinder on stand). Much could be done to promote the sharing of experience as regards improvements to simple implements. 'In many regions of the world, the use of improved hand tools and light animal-drawn implements and the application of better harness are certainly among the best methods of increasing . . . the efficiency of the cultivator's labour, thus permitting higher yields from the limited arable land at the disposal of the small farmer'—F.A.O. Development Paper, No. 32, Agriculture.

Tractor Width—The problem of whether to attempt to straddle tall row-crops such as cotton, and growing sugar cane or maize, appears to have settled itself with a little help from the engineers. Narrow versions of popular tractors are available which will pass between rows planted at 6 ft. Some special narrow tractors available from Britain, Italy and the U.S.A. will pass between rows planted at 5 ft. or less, but they lack the versatility and stability of the 'popular' tractor. Growers have shown themselves willing to adapt planting distances to the machinery available; thus we have seen the planting of sugar cane in 6 ft. rows in the West Indies and elsewhere to admit a rotary hoe, and the growing of maize in the Rhodesias in rows as wide as 7 ft. 6 in. through which a standard tractor can pass.

Many growers maintain that all soil cultivation processes should have been completed before the crop has become too high for a row-crop tractor to straddle, and it will be interesting to see whether the tendency towards

weed control by chemical sprays (as, for example, in West Indian sugar cane) will have any lasting effect on the need for narrow tractors in the tropics. Special ' tractor stilts ' can be obtained to convert several popular tractors into ' high arch ' type machines, but the practical utility of such machines may be very doubtful.

Structural Weakness in Machines—Tropical agriculturists frequently report that machines originating in temperate manufacturing countries are not strong enough to stand up to ' overseas ' conditions. This is rather a sweeping statement, and there is evidence to suggest that implements—and especially ploughs—are frequently put to work in conditions for which they were never designed. Every manufacturer cannot undertake to make equipment to suit every purchaser; but, considering the whole vast range of agricultural implements on the world market, it seems likely that all but the most exceptional requirements could be met by careful selection. Unfortunately, the farmer's choice is frequently severely limited by :

(*a*) restrictions on the use of foreign currency;

(*b*) lack of suitable sales agencies in his territory;

(*c*) his own knowledge of what is available;

(*d*) what happens to be in stock locally at the time he wishes, or is able, to buy.

It must also be remembered that many mechanized agricultural projects in the tropics are in their infancy and with the passage of time the land will become ' broken in ', just as labour and management, alike, will gain useful experience in how to use equipment to best advantage.

However, manufacturers who are particularly interested in the export trade have now accepted that the main purpose of mechanization in many territories, and especially in Africa, is to enable basic cultivations to be carried out earlier and faster than is possible by hand or animal methods. This frequently means that even completely cleared land which has already been cropped is rock hard, and ploughing resistances of more than 30 lb./in.^{2} have been recorded. In such conditions a heavy crawler tractor of approximately 100 b.h.p. would probably pull only three deep furrows, and very robust implements are necessary.

Ploughs—Interest in mouldboard ploughing is increasing in old-established areas, especially in certain parts of the highlands of Kenya and Northern Tanganyika where a particularly good job of burying surface trash and grass is required. There is high praise for the quality of the work done by British disc ploughs, but criticism of them on account of breakages. There are one or two exceptions which are praised by all. It is evident:

(*i*) that one or two particular models of American plough have a better reputation for reliability in Africa than any other plough;

(*ii*) that other ploughs (whatever their country of origin) are very prone to breakage in Africa;

(*iii*) that as farmers gradually develop their land the breakage rate is reduced, and that a heavy rate of breakage of implements must be accepted as one of the costs of breakages of land; (for example, in Northern Rhodesia the European farmers complain bitterly about the multitude

of breakages they have experienced with a popular plough, while in Kenya they complain only about the self-lift; similarly, equipment which had a poor reputation three to five years ago at O.F.C., Urambo, is now reported to be giving good service);

(*iv*) that there is now an opportunity for new ploughs to compete with the established favourites and the deciding factors will be (*a*) physical strength, (*b*) quality of work, and (*c*) agents' reputation for service.

SUMMARY

This paper describes briefly the background to the mechanization of farming in several tropical African territories, and mentions some of the progress that has been made in recent years in introducing modern standard equipment into the local agriculture. The high cost of mechanization is stressed, attention being drawn to the expense of supervision, other overheads, and spare parts. Some of the problems faced by machinery agents are described, but it is emphasized that they have a very critical part to play in the future development of mechanization. Finally, a number of technical developments are briefly reviewed under the headings of paddy production, damage to tractor tyres, tie-ridging, brush and weed control in perennial crops, mulch farming, tea, implements for animal or manual power, tractor width, structural weakness in machines, and ploughs.

(*Received February 1954*)

REFERENCES

Aten, A., Faunce, A. D., and Ray, L. C. (1953). 'Equipment for the Processing of Rice,' *F.A.O. Dev. Paper No.* 27, Rome

Commonwealth Economic Committee. 'A Survey of the Trade in Agricultural Machinery', H.M.S.O., 1952

Coquerel, A. 'Paddy et Riz de Cochinchine', Saigon

Hopfen, H. J., and Biesalski, E. (1953). 'Small Farm Implements', *F.A.O. Dev. Paper No.* 32, Rome

Mayne, J. E. (1950). 'An Approach to Mechanization in Tropical Agriculture', *Trop. Agriculture, Trin*, **27**, 1–3

— (1951). 'Mechanization in Primitive Agriculture', *Brit. agric. Bull.*, **4**, 14

Pereira, H. C. (1951). 'The Mechanization of Coffee Mulching', *Coff. Bd. Kenya, Mon. Bull.*, Nov.

Raeburn, C. 'Paddy transplanting'. Correspondence

Wright, S. J. 'Mechanization on tea estates (with special reference to Ceylon)'. Correspondence

Productive Land Use in Ceylon

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INTRODUCTION

Ceylon agriculture falls into two distinct categories, plantation and peasant. The former, which includes the tea, rubber, coconut and cacao industries, is relatively recent, after 1820. The cultivation of paddy, *Oryza sativa*, which provides the staple diet of the indigenous population, must, without doubt, date back to the beginnings of the Sinhalese. From the land use angle, however, the striking difference between the two categories is a topographical one. The peasant always restricted his crops to the relatively flat areas bordering perennial streams, while the recently-established plantations extend to the higher areas and even include the steeper hills and ridges. The availability of water would appear to have controlled the selection, by the peasant, of land whether for cropping or for homesteads. In the absence of water-bearing strata over the greater part of the Island the water supply for both domestic use and crops is always superficial, from perennial streams or tanks, where water is available even in the driest periods. Subterranean supplies (wells) are generally confined to the limestone areas in the north.

The soil profile explains both the presence of water in the perennial streams and the selection by the peasant of the areas for crops. The soil catena, *Figure 1*, which shows two regions corresponding to the two categories of agriculture, is the result of weathering through the ages in the heavy monsoon downpours and over the steep gradients characteristic of the Island. The finely divided products of weathering have travelled with the drainage waters over the unbroken rock to the lowest-lying areas. The heaviest

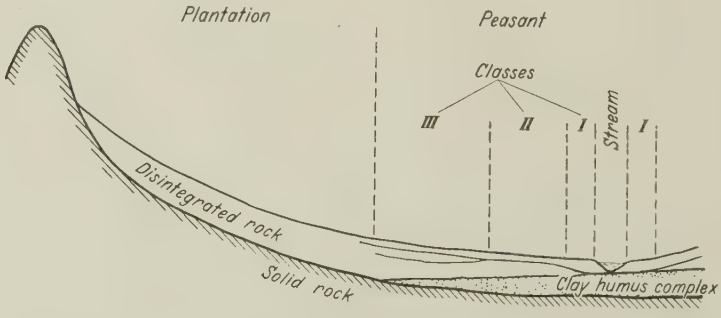

Figure 1. Soil Catena

colloids have also been carried down to the maximum depth of travel of the water, the intact rock. In perennial streams these colloids are superficial and in the adjoining land they are overlain by disintegrated but unweathered rock carried downhill by surface run-off. The lowest soil horizon,

because of the conditions under which it was formed, is made up of the ultimate products of weathering, humus and clay, the latter being of the montmorillonite type.

PADDY LANDS

In the areas cropped regularly by the peasant, three land classes can be recognized according to the number of horizons in the profile. Inasmuch as water is always present in changing quantities in perennial streams because montmorillonite clay is superficial, during the periods of heavy rain some of the water is forced by the increasing pressure into the overlying horizon in the lowest land class, which is then submerged. These lands are then used for growing paddy. Bone meal is the only fertilizer used by the peasant. Its low-lying position and the time of sowing, when the land is submerged, suggest that the flood waters supply the other nutrients. Paddy roots, like those of other grasses which tiller, show two stages of growth, a short and a long. Elongation usually begins in about 45 days from sowing in the *Yala*, the short south-west monsoon season, and in about 90 days in the long north-east, *Maha* (cf. HAIGH, 1936). *Figure 2* shows for the Peradeniya *Maha* 1931 crop:

(*i*) The profile depth, the first horizon being about 5·8 in.
(*ii*) The rainfall, which controls the soil moisture.
*(*iii*) The percentage rates of absorption of nutrients by the crop.
*(*iv*) The ammonia content of the soil.
(*v*) The stages of growth of the crop.

It will be seen that:

(*i*) The ammonia content of the soil which is high when the rainfall is high, decreases with the latter.
(*ii*) Tillering takes place during the period of high ammonia content.
(*iii*) Nevertheless, during this period, only a small percentage of potash and nitrogen is taken up by the plant.
(*iv*) After 90 days, that is after the roots have entered the clay humus complex, the uptake of both nitrogen and potash rises sharply.
(*v*) Flowering sets in after the nitrogen content of the soil has fallen considerably. This corresponds to a similar decrease in the rainfall.

It is, therefore, evident that the waters draining from the higher areas into the clay humus complex provide the nutrients for paddy, the vegetative and reproductive phases corresponding to the supply of nitrogen. It will also be seen that the nitrogen content of the soil does not, except at the start, differ appreciably from the control even after ammonium phosphate had been applied.

The science underlying the peasants' system of growing paddy can now be followed. Sowing, about 10 days before natural submergence, while there is still air in the soil helps seedling root growth. Submergence soon after sowing provides the nutrients in quantities suited to the crop's capacity for assimilation. Submergence is, however, determined by both the depth of the first horizon and the rainfall. The second factor also determines the period for which nutrients are available and therefore the age of the crop. Only bone meal is used because all nutrients, other than phosphorus, are supplied

* From JOACHIM *et al*, 1933, Plate II facing p. 17 and p. 29.

by the clay humus complex. This accounts for the high potash uptake, almost 60 lb. per acre by two crops year after year. Preparatory tillage is therefore superficial and only aims at killing any vegetation that preceded the crop.

Improvements in the methods of growing paddy have so far been based on practices general in temperate climates. In the belief that plant food has to be released from the land on which the crop grows, the operations are intensive. Tillage is, therefore, deep and frequent, begun long before transplanting or sowing, and associated with the incorporation of bulky organic manures. Ploughing is carried out before the soil moisture content has increased while there is still much air in the soil. The aerobic conditions accelerate the breakdown of organic matter and CO_2 is released. Weathering, which is the aim of all these operations, gradually produces silica and the kaolinite type of clay as in the equation:

$$2KAlSi_3O_8 + CO_2 + 2H_2O = K_2CO_3 + 4SiO_2 + Al_2O_3,\ 2SiO_2,\ 2H_2O$$

On the other hand, in the correctly-timed operation of the peasant, who stirs his land superficially with a single tooth, buffalo-drawn harrow, sufficient water is available to maintain anaerobic conditions and prevent the formation of CO_2.

As ploughing is continued deterioration increases and the indications change accordingly. In the early stages the minerals released in the first horizon stimulate the growth of such weeds as *Coix gigantea*, with high mineral requirements. Later, as less minerals become available, *Echinocloa spp.* thrive. After some time the denser, non-absorbent, kaolinite clay collects as a pan in the horizon in which it is formed. This prevents the roots from entering the second horizon and the crop shows signs of mineral deficiency, which cannot be corrected by the application of fertilizers. (KANDIAH, 1952). The greater proportion of minerals is taken up by the deeper roots which do not develop when the clay pan is formed. In an advanced stage of deterioration, when the pH rose but little, from 5·4 to 5·7 (JOACHIM *et al*, 1933, p. 31), the application of ammonium phosphate put up the nitrogen supply temporarily as shown in *Figure 2*. From a dressing of 96½ lb. ammonium phosphate an initial advantage of 1·35 mgm ammonia in 100 lb. soil was reduced in one week to 0·20 over the control. There was, nevertheless, an increase of 470 lb. per acre over the superphosphate treatment. The rapid decline in the ammonia content could not have been caused by its absorption by the seedlings, just transplanted, as paddy has no storage organs. The absorption is more likely by the rapidly growing blue-green algae common in paddy fields. These organisms, which normally get their supply of ammonia with the soil moisture rising from the clay humus complex, can fix no nitrogen when air is shut out. When other conditions are favourable they break down soil organic matter and release oxygen which helps the roots of paddy.

As deterioration proceeds the clay pan thickens and the rise and fall of soil moisture is interrupted. Rain water then stagnates in the field and *Isachne australis* becomes the dominant weed. Finally, as no soil moisture and therefore no cations can rise from the clay humus complex, the blue-green algae cannot function and any organic matter added to the soil remains

unchanged. The environment is ideal for *Salvinia*, which is spreading rapidly. This, in common with all ferns, grows in accumulations of organic matter when the pH is low. The peasant attributes the common weeds, *Cyperus dehiscens*, *C. Iria*, *Fimbristylis miliacea* and *Kyllinga spp.*, to insufficient water. If soon after sowing the rains fail, the soil moisture and with it the cations cannot rise automatically. The pH remains low and acid-loving

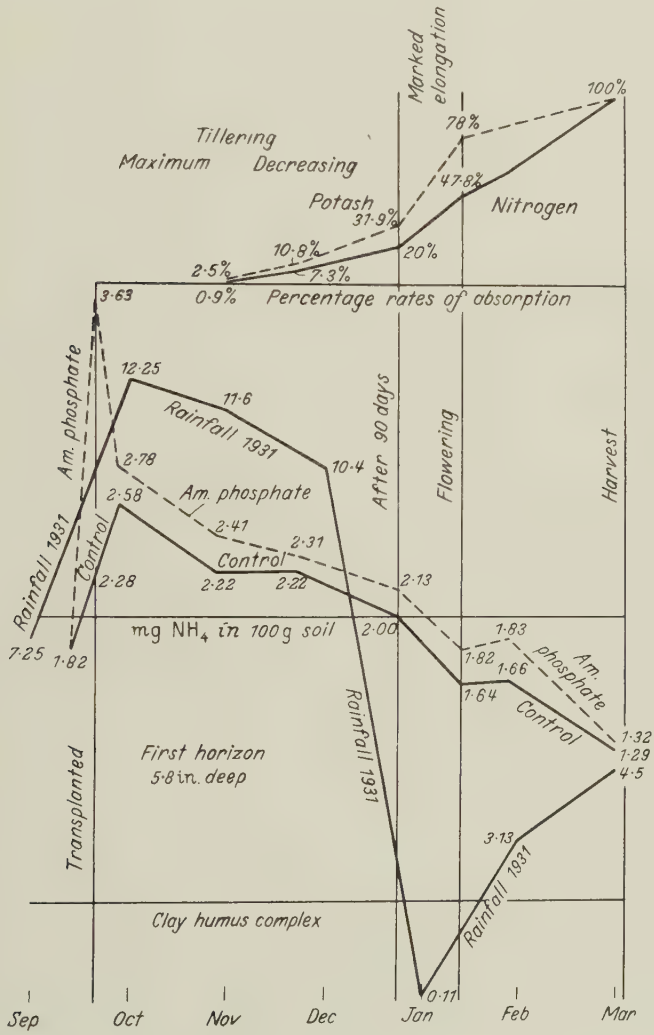

Figure 2

Cyperaceae thrive. The few weeds which grow even under ideal conditions of preparation are dealt with in the single hand operation which combines weeding, thinning out and supplying vacancies.

Irrigation maintains anaerobic conditions till the crop is ripe and the source of water is related to the extent sown. In the wetter areas the land is

steeper and the extent in any single tract is relatively small. Sufficient water is available in channels dug down to the clay humus complex in Class II lands adjoining the paddy fields. In the drier areas tanks in these lands, scooped down to the clay humus complex, irrigate the relatively flatter and larger extents. Thus the clay humus complex underlies both the land that is cropped and the source of water, which is close by. Unless these conditions are satisfied, weathering occurs in the horizon in which the crop roots. CO_2 released by the oxidation of the organic matter is in the drier areas readily neutralized by the higher base content characteristic of these soils. Less silica is then separated out in weathering and the clay has an intermediate silica–alumina ratio of 3 to 1 (JOACHIM and KANDIAH, 1942, p. 28). *Damanas*, the name for these formations, are plentiful in the areas now abandoned but cropped before in ignorance of the principles underlying land use in Ceylon. In the wetter areas the soils have less bases, less CO_2 is neutralized, more silica separates out and the clay has a lower silica–alumina ratio as in the *patanas* at high elevations (*ibid.*, p. 22). Because of its non-absorbent nature and its density, the clay released in weathering is eventually deposited as a pan. As the pan thickens, drainage and, consequently, aeration decrease, organic matter accumulates and the fern *Gleichenia linearis*, which gives its name to these *kekilla* lands thrives. (*ibid.* p. 25).

The conditions for growing paddy continuously on the same land can be summed up. There should always be:

(*i*) the clay humus complex which should lie directly under

(*ii*) a single horizon of disintegrated but unweathered rock. Hence the higher proportions of the finer fractions, clay and silt (JACK, 1923).

(*iii*) Organic matter in the first horizon.

(*iv*) Rains which bring ammonium and other, mineral, ions to feed the growing paddy and stimulate the growth of the blue-green algae which supply oxygen to the paddy roots.

(*v*) Anaerobic conditions, *viz.* irrigation water, to prevent the oxidation of organic matter, the formation of CO_2 and weathering in the first horizon.

The organic matter must be in a form that is readily broken down by blue-green algae and the roots of the grass that grew in the fields in the off season are best. The land is stirred superficially under anaerobic conditions to ensure that they are dead. Resistant material like compost is avoided.

CLASS II LANDS

Class II lands, which are cropped only in the areas with heavy rains in both monsoons, are in the others converted into tanks. *Figure 3* shows the profile of a typical Class II vegetable land, the rainfall which controls the soil moisture content, the succession of the vegetation throughout the year, and the planting, flowering and harvesting dates. As long as the soil moisture content is high, grass grows at the expense of the high nitrogen content (*Figure 2*). When the nitrogen content falls as the rainfall decreases, the grass is grazed down and dunged over in preparation for vegetables. These get their nitrogen from the surplus of the activity of the aerobic nitrogen-

fixing organisms, which derive their energy from the break-down of the organic matter, the dung and the grass roots, and their minerals from the same source as the vegetables, the cations in the soil moisture linked to the clay humus complex. The vegetable roots grow deeper as the rainfall and with it the soil moisture content decrease. As with paddy lands attention

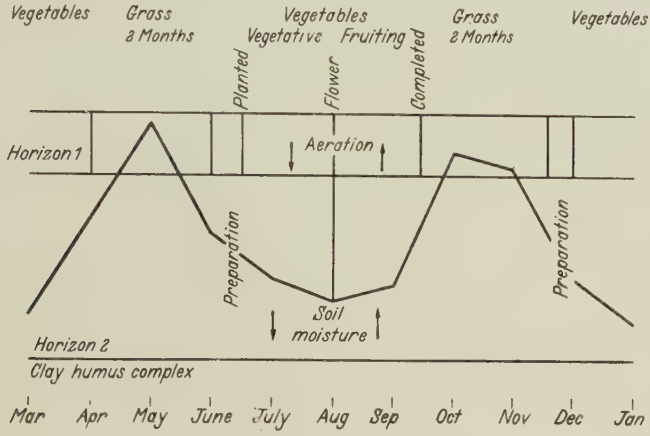

Figure 3. Vegetables in Class II lands

is little and restricted to scraping with a hand hoe to remove weeds, and hand watering. The water which is from pits dug in the lowest segments of Class III lands, raises the soil moisture content temporarily and improves the distribution, throughout the profile, of the cations. These benefit the nitrogen-fixing organisms and also neutralize CO_2 formed by the aerobic breakdown of the organic matter. Unless the rainfall is high, the moisture and nitrogen contents of the soil will not be enough to stimulate the growth of the grass, the roots of which provide energy for the nitrogen-fixing

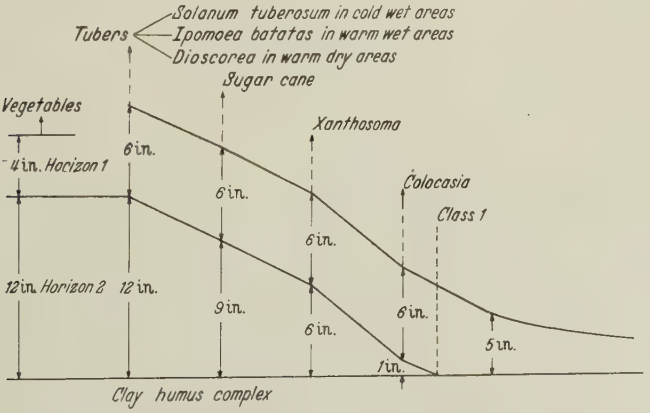

Figure 4. Range of crops according to profile depth in Class II lands

organisms. Besides, the availability of cations in the medium in which the crop roots will be low and weathering will result.

In the second stage of growth, the soil moisture content increases with the rains, less air and less nitrogen is availiable for fixation and for the crop, which then flowers. During the reproductive phase photosynthetic activity is coupled with an increasing cationic availability as the soil moisture content is rising. The association of carbohydrates and minerals in the fruit contributes to the nutritive value of the vegetable crops, chief among which is *Hibiscus esculentus*. In the sandier tracts of the wetter areas the dilution of minerals in the clay humus complex is reflected in the less firm, climbing cucurbits, *Trichosanthes anguina* and *Momordica charantia* with comparatively smaller leaf surfaces. With the same depth of second horizon, the duration of the grass which controls the age of the vegetable crop, depends on the depth of the first. The age of the crop can also be changed either by transplanting seedlings as with *Capsicum annuum* or *Solanum melongena* or by ridging the first horizon. The range of crops according to profile depth in Class II lands is shown in *Figure 4*. Because of both the greater depth of the first horizon and the marked seasonal variation of the rainfall some Class I lands, especially in the drier areas, are submerged in only one season. Their

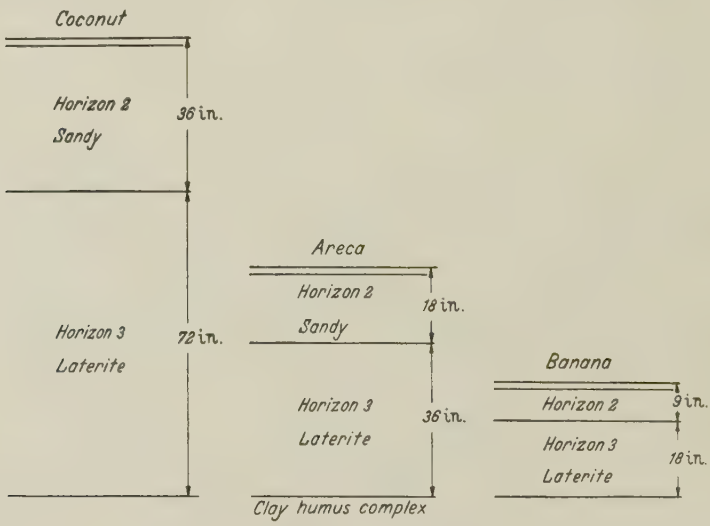

Figure 5. Range of crops in Class III lands

use in the second is according to the principle underlying the use of lands which do not get submerged, that is, Class II. In the driest areas, tobacco, *Solanum melongena*, *Capsicum annuum* or *Allium ascalonium* is grown according to the time available, and in the wetter areas the cucurbits already mentioned.

CLASS III LANDS

The use according to profile depth of Class III lands is shown in *Figure 5*. After the third banana sucker has fruited the land is fallowed and the natural vegetation burnt before the next cropping. The dead roots and ash provide energy and minerals respectively for the nitrogen-fixing organisms. The fallen fronds together with the sweepings and ash from the homesteads

provide ideal conditions for nitrogen-fixation in areca groves, while the palms get their minerals from the clay humus complex. On coconut lands, the husks and fallen fronds of the palm are burnt in the dry weather and the annual weeds die. Their roots provide energy for nitrogen-fixing organisms which become active with the rains in the presence of the minerals in the ash. The proximity of the roots to the clay humus complex ensures a constant supply of water and minerals to the palm. Aeration, which follows percolation of the rains into the profile, oxidizes the organic matter. The ash which dissolves readily neutralizes CO_2 and prevents weathering in the surface horizons. Class III lands are cropped regularly only in the areas which get sufficient rain in both monsoons. A deep profile underlain by the clay humus complex drains readily and unless sufficient organic matter is present in the surface horizon it dries fast in the intervals between the showers. This causes the fall of the tender newly-formed nuts. In very wet areas, specially if the profile is shallow, drainage is unsatisfactory and less air becomes available for nitrogen-fixation. Growth and fruiting are then poor. The ideal distribution of crops according to profile depth and rainfall would appear to be as shown in *Figure 6*. Only lands with relatively deep profiles in the zone of intermediate rainfall are suitable for coconut.

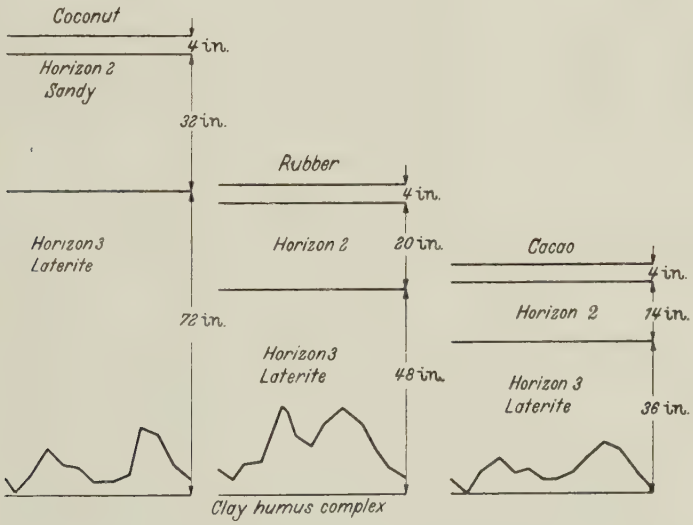

Figure 6. Distribution of coconut, rubber and cacao

THE CHENA

As no crop suitable for Class III lands in the driest areas is yet known, the natural vegetation is allowed to grow till it reaches maximum height when the jungle is felled and burnt and the land used for the *chena*, the name for this form of cropping. The ash from the leaves and smaller branches together with the accumulated organic matter, mainly roots, serve the nitrogen-fixing organisms. The nitrogen and minerals, including potassium and phosphorus, are taken up by the *chena* crops. Excess nitrogen is washed down to the clay humus complex where as ammonia it is used by paddy in Class I lands. Thus

the system of integrated land use, in all areas wet and dry, ensures a supply of nitrogen to the peasant's staple crop, paddy. If the jungle or the husks and other waste are not burnt periodically the supply of nitrogen will fail. As the jungle is burnt in scattered blocks, the supply of nitrogen to the paddy lands is assured. As the ash is gradually washed down, deeper-rooting weeds spring up, which cannot be eradicated by scraping the surface with a hand hoe. Further cropping when less ash is available on the surface will lead to weathering. The land is therefore reverted to jungle at this stage.

PESTS AND DISEASES

The prevention of weathering in the horizon occupied by crop roots is basic to all land use. The roots must always get their minerals from the clay humus complex. Crops can, otherwise, be grown only after a burn and then for about two years as in the *chena*. This holds for graminaceous fodders and pastures as well. Hillside grasslands on deep profiles are burnt periodically and the more succulent grasses are stimulated by the greater release of nitrogen in the presence of ash. As the ash is washed deeper, the vegetation becomes deeper and coarser, and burning is repeated. Whenever, as often happens through a misconception of the principle underlying land use, weathering is induced in the horizon of the crop roots, silica separates out and the kaolinite type of clay is formed. The land always passes through the same stages of deterioration, a deficiency of minerals at the start, a marked increase in new weeds later, and finally a thickened clay pan. The insufficiency of minerals leads to unbalanced nutrition and the crop falls an easy victim to pests and diseases. In the last stage the clay pan prevents the rain from entering the profile and carrying nitrogen to the deeper roots which die. They are then attacked by the saprophytic organisms generally associated with root diseases. Tillage under aerobic conditions, especially when accompanied by the incorporation of bulky organic manures, induces weathering.

FRUIT CROPS

It is essential that the changes in the rainfall, with which are linked aeration and nitrogen-fixation, should synchronize with the vegetative and reproductive phases of the crop. This explains the distribution of fruit crops—banana, lime, orange, mango and mangosteen. The burgeoning of the vegetative buds corresponding to tillering in cereals, coincides with the periods of maximum nitrification. The elongation of the shoots goes on as the soil moisture content decreases and the concentration of the cations increases. Flowering begins as the nitrogen content of the soil falls. Ripening takes place as the soil moisture content increases so that the juiciness is associated with the products of photosynthetic activity and minerals, all of which contribute to the characteristic flavours of the fruit.

TEA AND COFFEE

Until the introduction of coffee the areas above Class III lands were never cropped, a practice justified by the fact that it is here that the clay humus complex is elaborated and enriched. Crops can grow here only at the expense of minerals released by weathering, in the horizon occupied by the roots

where a clay pan forms eventually. How soon it forms depends on the intensiveness of the cultivation. As always, the first occurrence is a deficiency of minerals. The supply of the micro-nutrient copper fails and the plant is then unable to overcome, without assistance from sprays, the attacks of leaf-attacking parasites, *Hemileia* in coffee or " Blister Blight " in tea.

CONCLUSION

Error and elimination through the centuries must without doubt have taught the peasant to distinguish the flatter areas, where water is always available, from the steeper. The clay humus complex which is elaborated and enriched in the latter is exploited by crops in the former. This complex because of its readily absorbent nature, also increases infiltration and reduces run-off. Structure also results in the first horizon from the presence of disintegrating organic matter and cations either as such or as readily soluble ash. This does away with the need for mechanical measures against soil erosion. In the last analysis the peasant crops only soil, as defined by JOFFE (1949), the fundamental features being its natural occurrence, a mixture of organic and inorganic components, its differentiation into horizons, and its distinction from the underlying rock. The land use also satisfies the requirements of sound agronomy as laid down by BALL (1925) because it combines the art and underlying science of so handling the crop plant and the soil substrate as to produce the highest possible quantity and quality of the desired crop product from each unit of land, soil, water and light, with a minimum of immediate or future expense in labour and soil fertility.

SUMMARY

An examination of the traditional system of land use reveals that only lands underlain by a clay humus complex are cropped continuously. Roots reach down to the complex for their requirements of water and cations, while nitrogen-fixing organisms supply that element. Plant food is only absorbed but not extracted from the medium in which the crop roots and it is imperative that weathering should not occur there. This is ensured by the constant presence, during crop growth, of cations. In shallow profiles annuals are grown. When the rainfall and, with it, the soil moisture content decrease, irrigation, also from a source underlain by the clay humus complex, helps to increase the soil moisture content and raise the cations to the surface layers where any CO_2 that may be formed by the breakdown of organic matter is readily neutralized. In deeper profiles, where biennials or perennials are grown, ash serves this purpose and also stimulates nitrogen-fixing organisms. For areas, with only one rainy season and usually with deep profiles, a sufficiently deep-rooting crop is not known. The natural vegetation is burnt after it reaches maximum height in about 20 years. In this type of cropping, the *chena*, the nitrogen, fixed by micro-organisms, and the ash supply the nutrients. As the ash gets gradually washed down deeper-rooting weeds thrive. Shallow-rooting crops, if grown at this stage, can get the necessary cations only from weathering in the surface horizons. The land is therefore reverted to jungle. Surplus nitrogen washed from the higher areas down to the clay humus complex feeds paddy, the staple crop, in the lowest. This complex which is elaborated and regularly enriched in the higher and steeper

areas collects in the lower and flatter. This explains the system of integrated land use which also distinguishes between lands:

(*i*) with a clay humus complex and those without, and

(*ii*) of different profile depths.

(*Received April 1954*)

REFERENCES

Ball, C. R. (1925). *J. Amer. Soc. Agron.*, **17,** 661–675
Haigh, J. C. (1936). *Trop. Agriculturist,* **87,** 219 and 224
Jack, H. W. (1923). *Malay. Agric. J.*, **6**
Joachim, A. W. R., Kandiah, S. and Panditteseker e (1933). *Trop. Agriculturist,* **81,** 11–35
— — (1942). *Ibid.*, **98,** 15–30
Joffe, J. S. (1949). *Pedology, Leningr.* **41**
Kandiah, S. (1952). *Trop. Agriculturist,* **108,** 48

The Abyan Irrigation Scheme, Aden Protectorate

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A percentage of the rain precipitated on the High Yemen drains off into the wadis Bana and Hassan which ultimately disgorge their silt-charged waters on to the Abyan flood plain some 50 miles to the north-east of Aden in the territory of the Fadhli and Yafai States. Over the centuries a thick deposit of alluvium has been laid down over an area of some 120,000 acres. This area is generally considered to constitute, roughly, an equilateral triangle, whose sides are about 20 miles in length. Both the wadis enter the area at its northern apex, the waters of the wadi Bana meander down the western side and those of the Hassan along the eastern side of the triangle.

The vegetation indigenous to the locality comprises *Tamarix spp.*, *Salvadora spp.*, *Calotropis spp.*, *Zizyphus spp.* and *Acacia spp.* The climate in Abyan is warm in winter and hot and very humid in summer. Rainfall is scanty, in the neighbourhood of 2 in. per annum and is of little account for arable farming. The soil varies from a very light to a medium loam; all is alluvial in nature.

Sub-surface water is found at 50–60 ft. in some areas and at 12–14 ft. in others. The quality of water also varies considerably.

The flood water supply comes from the wadis Bana and Hassan. The Bana is much more important of the two. In addition to great floods (the discharge of one of which was recorded as 600 m^3/sec) it provides a perennial flow of limited volume.

Floods are subject to great variation. The first spate is expected in March–April. It may be enormous in volume, last a matter of hours only, and tail off into a small flow. Small freshets are expected in May. During the 40 days interval between the north-east and south-west monsoons no water is expected.

From the beginning of July steady freshets should arrive, with large spates now and then till mid-September. Thereafter a steady flow of 30–40 cusecs in the Bana for about three months has usually been experienced. The average discharge over the past five years was approximately 145,000,000 m^3 per annum.

There is evidence to show that irrigated farming was carried out in the past on a considerable scale, but in fairly recent years, agricultural activities were severely restricted by perpetual feuds, emigration, poor health and subsequent poverty.

With the establishment of more peaceful conditions the Agricultural Department entered the area in 1941 with the object of initiating a war-time food production drive. With the aid of a loan of £10,000 it rebuilt

all the possible diversion work in the southern area and brought 1,000 acres under cultivation.

In 1943, the Khanfar Development Scheme was inaugurated with further financial assistance from the same source. During the four years of its existence it brought an area of desert, bush and semi-derelict land approaching 5,000 acres under rough development to irrigated farming and repaid all its borrowings except a sum which was more than covered by its assets in livestock, grain and fodder.

In April 1947, on the termination of the Khanfar Development Scheme, the Abyan Board was set up. An agricultural officer was appointed as manager, and the advisory services of an irrigation engineer were secured. Initially the Board functioned on cereal production loans, then a loan of £20,000 was obtained from Colonial Development and Welfare Funds. Later a detailed scheme was prepared and in 1948 a further loan of £250,000 was secured from the same source. Up to this time the land was cultivated on traditional lines and only sorghum and sesame were grown.

The Board was modelled generally on the lines of the Sudan Gash Board. It is a triple partnership of:

The Board: Tenants: The States and the Landlords.

The Members of the Board are:

British Agent, Western Aden Protectorate	...	Chairman
Director of Agriculture	...	Managing Director
Political Officer, Southern Area ...	...	Director
Two Representatives (Yafai State)	...	Members
Two Representatives (Fadhli State)		
Agricultural Officer, Abyan	...	Manager

The functions of each partner are as follows:

(*a*) *The Board* erects and maintains capital works, main and field canals; prepares uncultivated land for irrigation; distributes water to the various areas ; prescribes the acreage to be laid down under different crops; provides collecting points and weighing facilities for crop produce; makes advances of seed and cash to tenants when necessary; gins and markets the cotton crop; distributes the sale proceeds.

(*b*) *The Tenant* maintains irrigation banks and the field channels on his holding; grows crops which the Board prescribes annually; cultivates according to the Board's direction and delivers his produce at approved centres.

(*c*) *The Landlord* is responsible for the cultivation of his own land either directly or through tenants. He is also responsible for debts owed by his tenants to the Board or to the States.

(*d*) *The States* provide land and other services such as security forces, schools, courts and medical facilities. The returns from the scheme are divided as follows:

		per cent
Board	... ...	25
Tenants	... ...	50
States and Landlords	...	25

Originally the Board took a quarter share of all crops. Now their share is only taken from the cotton crop and a water rate of £2 per acre is charged on all crops other than cotton.

In 1946, the Director of Agriculture conducted a trial with the long staple cotton variety X.1730A which derives from Sudan Sakel. Three to four acres only were laid down and results were disappointing due to late sowing in poorish soil. In 1947, due to other pre-occupations no cotton was sown.

In 1948, an area of 82 acres was sown on different classes of soil and an average yield of 1,750 lb. seed cotton per acre was secured. Ginning was carried out with one roller gin and the crop was purchased by the Raw Cotton Commission at a flat rate of 31*d.* per lb. Wishing to take advantage of the prevailing high world prices for cotton, the Board decided to step up production in order to acquire funds for accelerated development.

Their success in this direction is shown in *Table 1*, which shows cotton production from 1949 to 1952/53.

Table 1. Abyan Cotton Production

Year	*Acres*	*Yield*	
		Bales	*lb.*
1949–50	1,097	1,587	634,800
1950–51	7,000	9,954	3,991,600
1951–52	9,830	7,206	2,882,400
1952–53	11,300	11,066	4,426,400
1953–54 (estimated) ..	20,000	20,000	8,000,000

In the initial stages of development the Board used traditional methods of irrigation only. The water was held up in the wadi by the building of a series of earthen banks (mashas) and was pushed on to the adjacent lands which were built up in a series of bunded fields. When one field was filled a bank was broken and the water moved on to the next. The water duty by this method of irrigation is estimated at one metre depth. Similarly when one area was inundated the masha was broken and the water was allowed to proceed to the next one downstream.

With the recruitment of a resident irrigation engineer and staff, a team of surveyors was put in the field and a contour survey of the delta was produced.

Thereafter a regulator was built at the headworks of the Bana and a series of main canals with drops and gates were constructed. Work was facilitated and speeded up by the purchase of earth moving equipment, but still today the local teams of oxen with their traditional scraper-boards are fully employed.

The engineering section has a large programme for new capital works ahead, with an increasing demand for maintenance of existing works due to rapid expansion.

Since the introduction of the first roller gin in June 1949 a ginnery (the second to be constructed) with 32 gins and up-to-date equipment was

built at El Kod, the nearest point to Aden, in 1951. This ginnery produced 11,066 bales lint in the 1952/53 season.

A workshop supervised by a British foreman caters for the servicing and repairing of tractors and motor transport.

A small fleet of Ferguson tractors was introduced in 1953 and they are hired out to farmers mainly for deep ploughing for the eradication of Sida'a grass (*Desmostachya dipinnata*). Most of the ploughing is still done by the traditional bullock plough, but a number of farmers have purchased their own tractors.

The cotton crop is sown as soon as possible after the July–August floods. The rows are spaced about 3–4 ft. apart at a seed rate of 12–15 lb. per acre. Thinning and clearing starts from 15–20 days after sowing. The final spacing of plants depends on the fertility of the soil and varies from 1–3 ft. or even more. The first pickings are obtained in January–February from the most forward fields and picking continues until the end of May when the plants are uprooted and burned.

The services of a cotton consultant/plant breeder were secured in 1951. In addition to carrying out experimental work with other varieties of cotton he has now by selection from within the Abyan variety (X.1730A) built up a pure seed supply. This seed is sown in an area outside Abyan and distant from other cotton. The following year the seed from this area provides sowing material for the next Abyan crop.

By having a dead season for cotton and an annual influx of pure seed, it is hoped to keep pests and diseases at a minimum.

This practice has so far shown encouraging results; pink bollworm (*Platyedra gossypiella*) has not been found in the present crop, and while no serious damage was caused by other pests and diseases, the following have been noted and identified :

Sudan bollworm (*Diparopsis perditor*) destroyed buds and bolls in February.

American bollworm (*Heliothis armigera*) made sporadic attacks of some intensity during the first week of September.

Leaf Spot (*Cercospora gossypium*), which ultimately caused leaf shed, occurred in some areas.

Cotton Wilt (*Rhizoctonia*) and *Pythium spp.* were found in many low-lying areas and were often associated with soil of high alkalinity.

An unidentified fungoid disease (Leaf rim blight), which attacks the rim of the leaves and gives the appearance of a severe scalding, led to leaf curl, leaf shed and premature boll opening.

The traditional grain crop of Abyan is *Sorghum vulgare* (dhurra). A number of different varieties exist. After the March–April flood (Seif) dhurra is sown, giving a moderate yield of grain or a good yield of good quality fodder. If the flood is received very early bulrush millet (*Pennisetum typhoideum*) may be sown. In the northern part of the district where freshets are expected maize or melons may be planted. Harvesting occurs in July.

If early May–June floods are received, sorghum (Ghorba) is planted in the northern canal area. It is given two irrigations and produces heavy yields of both grain and medium quality fodder.

If the flood waters reach the southern areas in June, black sesame is sown in July and harvested in November.

When heavy floods are received in July August the northern area crops are re-watered and additional areas are sown with sorghum (Baini) (introduced by the agricultural department).

In the southern areas all the cropped land goes under a red sorghum either 'Za'ar' or 'Bukr'; both are good for grain and fodder. In order to avoid the sorghum midge this crop has a special sowing date between 20 September and mid-October. Inadequately irrigated land is sown to sorghum for fodder.

To some extent the arrival of the floods determine the crop within these narrow limitations.

Dwarf Hegari sorghum has been investigated under field trials and was better than any local grain sorghum except Baini. This promising variety is now to be tried as an early spring grain crop.

The desirability of including a legume in the rotation is fully appreciated and field trials have been conducted with lubia (*Dolichos lablab*) and pigeon pea (*Cajanus indicus*). Two varieties of lubia were grown, white flowered and purple flowered. They were planted late in August and germinated well. However, spacings were made too far apart for it to form a complete cover. A further trial on plant spacing will be conducted next season. Two varieties of pigeon pea—West Indian white and Central Indian red -did extremely well, making luxuriant growth and finally averaging 7 ft. in height. Five distinct pickings were made and the final yields of shelled grain were:

W.I.W.	...	4,599 lb. per acre
C.I.R.	...	6,375 lb. per acre.

These results are definitely encouraging when one considers that the average yield of this crop elsewhere is 600 lb. per acre.

Grown in combination with lubia this legume should be very useful in a rotation of cotton: sorghum: pigeon pea: cotton.

Other cash crops are also being investigated. In the northern area some 40 acres were laid down to sugar cane varieties, under perennial irrigation. The better varieties M 72/31 and P.O.J. 2961 yielded 40 tons of cane to the acre. In the first year an inferior product was produced under very primitive conditions. The following year 1953–54 four acres only were cropped to sugar cane, and due to experience, a much better sugar product was produced. The cost of production is still too high to make sugar production a paying concern in Abyan; however a nucleus stock of cane will be maintained.

A plantation of Dwarf Cavendish banana (*Musa sinensis*) laid out in the quincunx method at 12 ft. intervals and under regular irrigation has shown promising results. For observation purposes a further 250 suckers were set out on more alkaline soil, but they did not make good progress.

Outside the Abyan area, the Board has acted as banker to a number of small cotton producing schemes, and the specialist services of Board personnel have often been available to assist them.

Due to the facilities located on Abyan it has become the main experimental area for both agriculture and engineering, and information obtained there will be fully utilized throughout the Protectorate.

I have so far only mentioned crops raised by flood irrigation, or watered by springs. In addition to wells for the supply of domestic water, a number of shallow wells exist where the water is raised by animal lift. These irrigate small areas of up to four acres where vegetables are raised during the winter season and melons and spices are grown during the summer. In order to investigate and exploit sub-surface water supplies following the recommendations of Sir Herbert Stewart in 1950 and Sir Geoffrey Clay's mission in 1951, a tube-well programme has been initiated and is now in progress. Details of the findings are not yet available.

Also on the recommendations of the above, plans to recruit a full research team to assist the present consultant/plant breeder have been made. The team will consist of a plant-breeder/agronomist to work on cotton and other crops, a soil chemist to investigate problems of soil salinity, and an entomologist.

The future policy of the Board remains as previously defined:

(*a*) To utilize all surface flow and suitable underground supplies of water in order to develop and maintain irrigation in the Abyan district.

(*b*) To organize and develop the production of food crops and cash crops and to assist in their marketing.

(*c*) To increase the wealth and prosperity of the people and governments of the local states and of the Aden Protectorate.

In order that essential supplies of grain, fodder and oil-seeds may be maintained, no large increase over the present cotton crop acreage of 20,000 acres is anticipated.

An increase in the area irrigated from wells, however, is envisaged, with an expansion in the production of vegetables and fruits.

In 1943, Gi'ar, the present headquarters of the Board, was a hamlet about the shrine of Abu Shamla, and there were some 10 brushwood huts inhabited by the Mansab and a community of charcoal burners.

Ten years later Gi'ar is now a township of some 5,000 persons, with school, doctor, dispensary, and streets lit by electricity and shaded with trees. The Board employs a salaried staff of 148 persons comprising: 15 British, 6 Italians, 1 German, 6 Greeks, 111 Arabs, 6 Indians, 2 Sudanese and 1 Persian, indeed a cosmopolitan society.

The Balance Sheet at 30 September 1953, shows that the total assets of the Board amount to £1,463,710, of which approximately £750,000 is in cash or investments at short call, and the remainder in plant and equipment and fixed assets.

The current liabilities include £40,000 in a Sinking Fund towards repayment of the initial loan ; £200,000 to a Revenue Stabilization Fund, and £400,000 in a General Development Reserve.

Tribute is due to the vision which saw the possibilities of this territory initially, and to the energy which those responsible for the development of the scheme have applied, and daily apply, to overcoming the multitude of problems which constantly arise in a pioneering venture of such a nature.

(*Received April 1954*)

Schemes for the Improvement of African Farming in Northern Rhodesia

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'Do any of us understand what we are doing ? If we did, would we ever do it?'
Bernard Shaw—Pygmalion

There are two main schemes for the betterment of African farming in this territory. The first is the Improved Farmer Scheme which applies in the maize producing areas of the Southern and Central Provinces. The second is the Peasant Farming Scheme for more backward areas where cattle may have to be introduced to traditionally forest people. Efforts are now being made to extend this scheme into the Improved Farming areas and thus cater for the prospective African farmer with limited resources.

IMPROVED FARMING SCHEME

Finance. This is financed from the African Farming Improvement Fund which is built up from the annual balances on the Native Maize Pool operated by the Maize Control Board. The Fund is held by the Accountant-General. It is administered by a Chairman and the Provincial Commissioners of the Central and Southern Provinces, the Commissioner for Native Development, and the Manager of the Maize Control Board, and two representative Africans from each province are members.

The funds are used in the maize producing areas of the Southern and Central Provinces *i.e.* mainly in Mazabuka, Mumbwa, Broken Hill and Lusaka districts. The expenditure is co-ordinated for each province by the Provincial Development Teams and finally approved by the Committee. The largest proportion of the money made available annually goes to the Departments of Agriculture and Water Development and Irrigation, smaller amounts being allocated to the Provincial Administration mainly for road work and Native Authority water schemes.

Aim of the Scheme

The object of the scheme is to pay a bonus to African farmers who farm their land on the basis of recommendations laid down by the Department of Agriculture. These recommendations represent a marked advance on the traditional methods employed and aim at permanent mixed farming.

Details of the Scheme

Provision is made for three types of Improved Farmer according to the size of holding and the ability of the individual concerned. The first-grade farmer must adopt a four-course rotation using fertilizer and farmyard manure on his maize and practising green manuring with a suitable crop such as Velvet Beans or Sunnhemp. The second-grade farmer must similarly adopt a four-course rotation, but need not use fertilizer or green

manure. He must manure his maize and crop half his land with suitable legumes. A third grade is available for farmers with a small acreage not exceeding 10 in all. They are permitted to plant three-quarters of their acreage to maize provided the remaining quarter is sown to a legume. The maize must be manured and fertilized.

The rotations recommended are:

First Grade:
Maize manured 5 tons F.Y.M. per acre
Sunnhemp ploughed in
Maize fertilized
Groundnuts, beans, *etc*

Second Grade:
Maize manured 5 tons F.Y.M. per acre
Groundnuts, beans, *etc*
Maize manured
Groundnuts, beans, *etc*

Third Grade:
Maize manured and fertilized
Maize ,, ,, ,,
Legume
Maize

Originally the fertilizer recommendations involved the application of 150 lb. per acre of superphosphate or super and raw rock phosphate to the maize crop. Owing, however, to the remarkable responses which have been obtained from applications of ammonium sulphate to the growing maize crop, the tendency is now to switch over to a recommended side dressing of up to 200 lb. per acre of this and to dispense with the phosphate. On demonstration farms the practice is being adopted of applying a replacement dressing of superphosphate to the Sunnhemp crop before this is broadcast at the rate of about 50 lb. per acre and following up with side dressings of sulphate of ammonia on the succeeding maize crop. It will, however, be some time before the African farmer can be persuaded to adopt a procedure of this sort and in the meantime a farmer is permitted to choose either to apply phosphate to his maize broadcast before sowing, or to side dress with ammonium sulphate according to the responses he has obtained on his own land.

This arrangement is working satisfactorily and is developing ' fertilizer consciousness ' amongst the farmers. The distinction made is that between ' sugar ' and ' lime ', the former resembling sulphate of ammonia and the latter superphosphate. Lime is generally known from its use as a whitewash on buildings. These fertilizers are at present ordered and distributed by the Department of Agriculture with the assistance of the transport of the Maize Control Board. Owing to the high price of nitrogenous fertilizers in Central Africa the fund applies a 50 per cent subsidy to sulphate of ammonia bringing it within reach of the Grade A farmer. Superphosphate is subsidized by the State.

A bonus is paid on each acre of arable land farmed in accordance with the scheme.

To further the aims of the scheme the Committee has recommended progressive increases in the rates of bonus payable during the past few years. This has been made possible by the increased price paid for the maize crop in the territory. Bonus payments since 1950 have been as follows:

	1950	1951	1952	1953	*Recommended* 1954
Grade A ...	18*s.*	21*s.*	22*s.* 6*d.*	25*s.*	27*s.*
Grade B ...	9*s.*	12*s.*	13*s.*	15*s.*	17*s.*
Smallholder ...	18*s.*	21*s.*	22*s.* 6*d.*	25*s.*	27*s.*

The result of these bonus payments has been a progressive increase in the number of farmers who have volunteered to register under the scheme and subsequently qualified for bonus. In 1950, 252 farmers received the bonus, whereas in 1953 nearly 1,000 were rewarded for their good farming. The average acreage of individual farms was approximately 17 in 1952. The demonstration value of registered farms is an important feature of the scheme.

Acreages and Yields

The tendency in the Central Province has been for individuals to register and then to set about the task of increasing their cleared acreage to compensate for the reduction in the effective maize acreage imposed by the rotation. For example, in the Sala Reserve bordering on the Kafue Flats the average acreage per farmer has increased as follows:

1951–2	1952–3	1953–4
20·35	25·90	37·50

The 1951–2 season was the first year of the scheme in this area.

It is estimated from sample weighings that maize yields obtained by Grade A farmers are about twice as good as those obtained by traditional methods where conditions are comparable. Results have not been so good on Grade B farms and it is thought that this grade should be regarded only as a step to Grade A and not a permanent method of cultivation.

There has been a noticeable increase in the production of pulse crops since the inception of the scheme, but investigations are proceeding to ascertain the most suitable varieties for the different areas. In general yields from the legume break in the rotation have not come up to expectations particularly in the case of groundnuts.

Water Supplies

As indicated, money is made available from the Fund to finance dam construction and the provision of watering points for cattle. This is done to overcome the difficulty experienced by farmers in collecting their cattle in good time to get their maize planted with the first rains. Yields of maize have been shown to decrease progressively each week that planting is delayed from the onset of rains until early January, after which it is too late anyway. It is customary amongst the maize growing tribes for the cattle to be left to wander freely after harvest and they migrate, often unherded, towards the permanent water supplies of the Kafue Flats and Lukanga Swamp. Once the first rain has fallen a frantic search for his oxen is initiated by the farmer and his family, and it may be some weeks

before they are found. The inevitable result is late planting and a reduced yield. The provision of dams, weirs and wells with troughs according to the site is therefore of first importance.

Soil Conservation

Attention is also given to the problem of erosion, not only in the cultivated lands, but also on paths and roads. Permanent contour banks are erected for the farmer using machinery based on agricultural stations and which is the property of the Farming Improvement Fund. In the more impermeable soils graded contour banks are constructed with suitable run-out strips. On the more porous soils banks are constructed on the true contour. The vertical interval used varies with the slope. Where African staff cannot be closely supervised a standard vertical interval of 3 ft. is adopted.

The problem of erosion on roads and paths is tackled through the medium of a subsidy (50 per cent of purchase price) on ox carts. Most of the trouble is caused by the use of sledges consisting of the cut-down fork of a sizeable tree on which is erected a basket type container, the whole being dragged along the road by ox and chain. This was at one time the standard method of delivering maize to a buying depot. The cart subsidy scheme has, however, resulted in a great increase in the number of carts owned. They are available to any maize grower whether registered as an Improved Farmer or not. Consideration is now being given by Native Authorities in the Southern Province to the total prohibition of the use of sledges and this should finally check the serious wash on the roads in this province.

Other aspects of the scheme include the erection of permanent stores at rural maize-buying depots and the distribution of scales to facilitate the sale of the crop to depots.

Loans

In order to ensure the continued expansion of the scheme it has recently been decided to make a limited sum available for issue to farmers as individual loans. The object of such loans is to facilitate the acquisition of necessary implements and the erection of simple farm buildings. They are also designed to help the farmer who is short of cash to purchase fertilizers and seeds. The main security in respect of these loans is the bonus which may be withheld to clear debts. The grant of loans is decided locally in each district by a committee consisting of the local agricultural officer, district officer and Native Authority representative.

Expenditure

Total expenditure on this scheme in the two provinces is now running at an annual rate exceeding £100,000.

Future of the Scheme

The Scheme has certain obvious short-comings. Its voluntary nature sometimes tempts the farmer to resign for a year or two and cash in on the improved fertility by cropping the whole area to maize. With a noticeable decline in his fortunes he then seeks to rejoin. This can, however, be mitigated by local administrative measures such as withholding the bonus for one complete season after rejoining.

The next step is to work towards the closer integration of the stock into the farm. In order to control weed growth it may prove necessary after six years or so of continuous cropping to put the arable lands down to grass and to open up a similar area of adjacent land for future cropping. With this in mind, in the Central Province attempts are made to see that each Improved Farmer has an area of land adjacent to his present fields which will be suitable for cropping in a few years time. When the time comes for land to go into grass it is hoped to make a start on the feeding of leys. Already farmers are beginning to fence their arable lands as a protection from stray cattle. From these beginnings it is intended to start teaching the management of cattle in seeded grass paddocks. The balancing of stock numbers according to the size of holding will be a longer step, but must come sooner or later according to the state of development of the district or parish.

In the meantime, it is the purpose of the demonstration farms to arouse interest in grasses and start an educational process which will obviously take some time to mature as far as the African peasant is concerned.

PEASANT FARMING SCHEME

The African Peasant Group Farming Scheme was initiated by the Development Authority in 1948.

Aim of the Scheme

The main object of the scheme is to bring about a permanent improvement in the standard of agricultural practice in native areas capable of supporting settled agriculture.

The aims are to wean the native cultivator from his traditional systems of shifting cultivation to a settled system on a tenant farming basis which will maintain soil fertility and preserve natural resources. By anchoring the population and concentrating it on the more fertile areas a higher standard of living will be possible including improved social services. With the development of a tenant farming system it is possible to inject more capital into native agriculture. At the same time by settling peasants in groups co-operative effort becomes feasible.

The essence of this scheme is that the change from shifting cultivation, more often in Northern Rhodesia a ' chitemene ' system, is made at one move.

The need for such a step is apparent particularly in the ' chitemene ' areas of the territory. Here the balance of nature has been suddenly upset by an increase in the native population in recent years. This has been accelerated by various factors, not least, no doubt, the *Pax Britannica*, improved health services and the industrial development of the territory. By ' chitemene ' is meant a system whereby areas of forest are chopped down, the timber piled in heaps of various shapes, often round, and the whole burnt just before the onset of the rainy season. In the resulting ash beds various crops are sown, the most general one being finger millet (*Eleusine coracana*). Considerable areas of forest are consumed by these methods. For instance, measurements made in Serenje district in 1953 indicated that one man would cut over 18 acres and concentrate the branches on an area which finally resulted in just over three-quarters of an acre of ash seedbed. A

village of 10 adult males thus requires over 180 acres of woodland annually for subsistence. The typical *Brachystegia–Isoberlinia* woodland takes much more than 30 years to regenerate after cutting for ' chitemene ' gardens, and it can therefore be readily appreciated what vast areas are required to support a small village in perpetuity.

It was this sort of background which stimulated the idea of Peasant Group Farming as it was becoming increasingly obvious that garden cutting was overtaking regeneration of woodland in considerable areas of the Northern and Central Plateaux. Attempts to rationalize the ' chitemene ' system itself had not produced a situation in which rural development could be contemplated, as for example the ' Chitemene Control ' scheme in the northern districts of the Northern Province, although, of course, the scheme has proved valuable in protecting important watersheds of the Luangwa and Chambesi–Luapula river systems.

To turn a forest dweller, whose main implement is the axe, into a ploughman is not an easy step to contemplate, and it is fully realized that quick results are not likely, especially when taking into account the poor physical capabilities of some of the tribes involved.

Details of the Scheme

Experimental groups of peasant farms were established in 1948. Groups of 10 volunteers were sought and these were then settled in chosen areas thought to be suitable for such development. Farms were surveyed and laid out in blocks of varying numbers according to topography and soil. Provision was made for water supplies and, if possible, irrigation. Fuel areas were demarcated and grazing areas set aside. Housing was sited either individually on each farm or in groups according to preference.

The Arable Lands

It has been necessary to clear the arable lands by hand labour with the assistance of a winch in suitable areas. The cost of this has been entered against the farmer as a repayable debt. The extent of arable land cleared varies from 8 to 20 acres. The aim is a high standard of crop husbandry on a small acreage including green manuring, dunging, a grass fallow and the use of fertilizers. The actual arable acreage depends as much as anything on the energy and ability of the individual farmer.

The normal procedure is to contour ridge all the arable lands from the start. The contour banks are then used as field boundaries for purposes of rotation of the crops.

Implements

In general a simple set of implements has been issued to the farmer on a repayable loan basis. The set includes a plough, harrow, cultivator, trek chains and Scotch cart, and in some cases a single-furrow planter and a ridging plough. In the more progressive areas some of these items may be owned already by the farmer. In order to keep the debt of each individual within his capacity to pay off in a reasonable period (10 years) it has sometimes been necessary to issue such implements as Scotch carts on a group basis. It is more satisfactory for each man to possess his own; he looks after them better and, of course, the planting season is so relatively brief that delays occasioned by communal ownership are intolerable.

There can be little doubt that the psychological effect of issuing the individual peasant with his own set of implements is very beneficial. A situation of trust and confidence is created from the start and most individuals respond to it.

Livestock

The management of the cattle varies from district to district according to circumstances. Under ideal conditions farmers bring their own cattle into the scheme. In other areas where cattle are normally kept but the prospective farmer is unable to provide his own, he is issued with two or three working oxen and if possible a cow. These are entered as a repayable loan. In forest areas where cattle have to be introduced a herd is allocated to a group and a similar number of cattle have to be returned to Government after five years. The natural increase belongs to the group. In addition each farmer in the group pays hire charge of 15*s*. per annum for the loan of cattle for ploughing and other work. The group method has not proved entirely satisfactory through irresponsibility in regard to such matters as herding, tick control and kraal cleaning; cattle need the personal attention of an individual owner.

Soil Fertility

In the early stages of the scheme some groups of farmers were sited on soils of indifferent fertility before suitable systems of crop rotation had been worked out for the particular area. In these cases there is still some doubt as to how the long bush fallow of shifting cultivation can be economically replaced by an accelerated restorative ley. Where fertilizers can be economically used, as in the railway line area, the problem is less acute; but in the remoter areas no ready solution has been found and there is now some doubt as to the wisdom of initiating such schemes in these areas.

Land Tenure

An agreement between each peasant farmer and the Native Authority is normally signed. The agreement takes the form of a lease and contains details about the loan of equipment and cattle, the clearing of land and the type of husbandry to be practised, together with certain restrictions on the number of relatives that may settle on the farm, and absenteeism on the part of the farmer himself. Details vary with local conditions and the intelligence of the occupants.

Finance

The scheme is financed throughout the territory from a revolving fund amounting to £250,000 generously provided from Colonial Development and Welfare Loan Funds. Repayments are credited to the fund and re-issued to new groups as the need arises. Certain non-recoverable expenses, such as the construction of access roads, surveys and experimental works, are financed from territorial funds.

The average cost of starting each farm is approximately £100, and this sum is repayable over a period varying from 10 to 20 years. More prosperous farmers generally repay sooner. Incomes vary on established farms from an average of £20 per annum on the poorer plateau soils in Serenje

district up to £192 on fertile Upper Valley soils at Katete in the Eastern Province.

Progress

At the time of writing the total number of peasant farmers is about 300 in groups throughout the central, eastern and northern provinces of the territory. Progress has been steady, not spectacular, and while the scheme has had an appeal to the poorer sections of the rural community, the more prosperous African farmers in the maize areas have preferred to develop in their own way. In general, the idea of being regimented together in geometrical groups has not appealed to the progressive African farmers along the railway belt, and there has in consequence been a certain ' holding back ' from the scheme to see how it develops. In some areas individual farmers have been accepted in the scheme and these tend to become the nuclei of new groups.

In the poorer rural areas the limiting factor appears to be the lack of sufficient suitable resident human material to take advantage of the opportunity offered. In some of the ' chitemene ' areas as much as 70 per cent of the able-bodied male population may be away working in the mines or elsewhere leaving the least likely material for such developments as these.

GENERAL CONCLUSIONS

In the administration of these two schemes many lessons have been learned and it may be of value to list some of them.

First, in the clearing. The tendency in the beginning was just to clear everything. This was a mistake and the value of leaving frequent windbreaks of the indigenous timber in wooded areas has become apparent. Very large trees are generally uneconomic to remove and should be left together with particularly useful species such as *Parinari mobola* (' Mupundu ') the large evergreen which produces an abundance of fruit used for food and drink. A few trees in the arable lands do not matter and provide useful shelter from the hot midday sun for cattle if the land is put down to pasture.

The provision of firewood areas is also most important once the supplies of wood from the initial clearing are exhausted.

It has been found in practice that the actual shape of the farm is of no great importance provided it is aligned on the contour, but in general peasant farmers prefer not too wide a farm, say 110 yards, so that the furrow is not too long and progress in ploughing appears to be more rapid. The more experienced Improved Farmer, however, prefers a wider farm.

Water supplies should be as simple as possible. Wells, dams and weirs are most suitable. Deep well pumps and boreholes require constant maintenance and are always giving trouble with African use.

It is most important to finalize the layout of a farm right from the beginning. Much irritation is caused to the farmer when an inexperienced African assistant lays out his contours inaccurately and these must be subsequently altered or scrapped altogether and sited elsewhere.

To avoid confusion field boundaries should also follow a contour rather than a straight line. Future extensions intended by the farmer should be taken into consideration, as far as possible, at the time of laying out. These

can then be brought into the farm in an orderly manner following the contour layout.

Time spent on siting access roads properly right at the start of a scheme saves much wasted effort in re-alignment as plans develop.

Individual ownership of implements and cattle is much to be preferred in Northern Rhodesia. Individual responsibility is established from the beginning and education in cattle husbandry proceeds more rapidly.

The establishment of Peasant Farming in marginal areas may be justified socially, but not economically. Marketing may become an acute problem under such conditions and the maintenance of soil fertility costly.

The writer is indebted to the Director of Agriculture for permission to publish this article.

(*Received March 1954*)

The Impact of New Grasses on Agricultural Development in East Africa

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The advance of western civilization and the progress of administration in East Africa during the past 50 years have resulted in a greatly increased population of both people and domestic animals. The rate of increase has accelerated in recent years, as administrative measures have become more effective and the fruits of scientific research have been applied in certain directions. The basic factors which have led to this change are the abolition of tribal warfare and a growing degree of control over disease in man and animals. There has been a natural tendency for population to concentrate in the moister parts of a region over much of which moisture is deficient. Also, the agricultural tribes which occupy these climatically favoured areas no longer demand merely a subsistence diet from the land, which could in the past be supported by shifting cultivation while the population was sparse; as a result of their contact with civilization, they seek to satisfy newly-acquired wants through the production of cash crops. The preservation not only of soil fertility, but of the soil itself has become an urgent problem in the areas capable of producing crops by virtue of sufficient rainfall. Further, with the ever increasing pressure of population in these areas there is a constant tendency for the spread of cultivation into the adjoining drier regions, with consequent rapid destruction of the vegetal cover and the onset of soil erosion (Edwards, 1951). Parallel with the growth of this problem in the agricultural areas is the great increase of livestock in the areas occupied by the pastoral tribes, resulting from the control of the major diseases of cattle and leading to severe land deterioration in localized areas. Such control is exercised to some extent in the interests of European stock farming within East Africa and in neighbouring territories, but it is regrettable that in this case, as with other advances attained by modern science in Africa, essential complementary phases of development often lag far behind.

Parts of both the moist and drier areas of the highland regions of Kenya and Tanganyika are occupied by European settlement. Here the extensive holdings concerned are, in the main, capable of more complete development than has yet been attained. Advanced methods of utilization are by no means in general use, and in many parts of the region deterioration similar to that of the native lands is in progress, although to a less degree.

In Kenya, five major ecological regions have been recognized, which also cover considerable parts of the adjoining territories (Edwards and Bogdan, 1951). These regions are defined by clearly distinguishable plant communities. Apart from a narrow coastal belt, the possibility of arable crop production is practically confined to the regions of the two moist communities, the ' Highland Grassland and Forest ' and the ' Scattered Tree Grassland (Low Tree–High Grass) '. ' These two vegetational regions

together represent less than one quarter of the total area of Kenya. Concentrated within them is possibly some 90 per cent of the population (with a density in some parts of the native areas as high as 800 per square mile) and about half the stock population of the country, despite the fact that the place of stock in the life of the agricultural tribes is secondary to crop production. These facts serve to emphasize the urgent nature of the conservation problem which confronts East Africa.

Under the high temperatures of tropical climates which, even in the more moist regions, include periods of marked drought, the condition of the soil is less stable than in the temperate zones. The foremost factor in the extensive and advancing deterioration is breakdown of soil structure under arable cultivation, which is closely related to capacity to absorb and retain water and to the onset of soil erosion. This breakdown appears to be especially rapid under the climatic conditions, and its effect in reducing the available moisture is often critical in the drier regions of crop cultivation. The immediate necessity is to provide for a periodical soil cover in the crop rotation, and moreover, a cover which will not throw the land out of use for years at a time as does the present bush fallow of shifting cultivation. It should be appreciated, however, that the necessity is more urgent than this statement appears to imply, since the bush fallow has virtually disappeared in parts of the African lands owing to the demands of food and cash crops by an increased population, and more or less continuous crop cultivation has replaced it. Artificially established, temporary grass as an essential part of the arable rotation is the most important instrument which can be provided by the agricultural technician to check this downward trend in the physical state of the soil (MARTIN, 1944). The necessary advance in method implies, of course, a much closer relationship than hitherto between the animal and crop cultivation.

THE AGRICULTURAL GRASSES

As the vital necessity was recognized in tropical agriculture for a periodical grass cover, which would induce recovery of soil structure and provide an opportunity for the accumulation of organic matter directly and also by the concentration of animals on the land, a search for grasses and other plants suited to the purpose began. This work naturally started with the trial of material which had already been proved in other parts of the world. However, the agriculturally developed countries are mainly outside the tropics, and although a few of these introduced plants gave promise in special and limited areas, almost all of them failed to survive in the new environment. It soon became evident that main attention should be directed to the indigenous flora, where a rich field of study awaits the investigator. This has been the experience in all three of the East African territories, and it may be safely assumed that experience in most other regions of the tropics has been similar. Although the trial of exotic plants continues, it is noteworthy that, with few exceptions, the most successful is the local indigenous material, and next, that which comes from other parts of the African continent, provided the areas of origin are of somewhat similar conditions. A wealth of fodder plants is to be found in the natural vegetation which has developed in association with large numbers of wild animals and which

now also supports numerous domestic herds. An important phase of the work at present in progress is that of evaluating these plants for the required purposes of artificial establishment, and the present discussion therefore refers to material which is new only in the sense that it has recently been introduced to cultivation.

The existence of marked ecological regions in East Africa has already been mentioned. The plant communities defining these regions are determined mainly by moisture and temperature, associated with elevation and aspect of the land, producing environmental conditions far more strongly contrasted than is usually the case in temperate regions. It is, therefore, essential that an ecological approach should be made, not only to the grassland problems, but to those of development in general. The range over which a plant is successful can be somewhat increased under cultivation, but experience has shown that most of the indigenous grass species give their best results within the region of a major plant community where they already occur naturally. Of course, some species have succeeded in adapting themselves in the natural vegetation more widely than others and they are common to more than one community. The occurrence of the main vegetation types often as several isolated aggregates has tended to induce the development of ecotypes or geographical strains of their constituent plant species, and in the case of the grasses, this provides a particularly fruitful field for selection.

In the search for indigenous plants to meet the urgent requirement of temporary pasture in the crop producing areas, comparison has been made on the basis of the following main qualities; (*a*) palatability, (*b*) ease of eradication when required, (*c*) good seeding properties, and (*d*) ability to persist under intensive management. Few of the grasses tested conform to all these criteria, and most have been discarded on account of failure to satisfy the last two. It is an unfortunate fact that few of the indigenous species have good seeding qualities, and there is a measure of controversy as to the importance of this factor. It is probable that some advance may be made in native agriculture by the use of grasses dependent upon vegetative establishment, but the view is held that a plant which is destined to attain importance in development must be capable eventually of providing a commercial seed supply. From the viewpoint of the research worker also, there is always the danger that grasses dependent upon planting rather than sowing will remain indefinitely at the stage of small plot trials instead of attaining a place in practice through commercial channels. Certain special requirements of soil conservation are somewhat different from the above. In the case of material used for binding earth banks, for example, seeding qualities are of secondary importance, while grasses with underground stems, which are too difficult of eradication for temporary pasture, are occasionally an advantage for this purpose.

Attention has been drawn to the tendency for crop cultivation to spread into drier areas where the environment cannot support it without rapid deterioration. This is mainly a result of congestion in the native agricultural areas, but in addition, the safe climatic limits of soil cultivation appear to be imperfectly understood in East Africa. If the view is taken that the range of arable agriculture properly coincides with that over which temporary

pasture can be reliably established and utilized, in order to safeguard the physical properties of the soil, it is found that an average 30 in. of rainfall per annum approximately represents the lower limit.

Comparatively few grasses have yet been successfully introduced to agricultural practice, and these mainly in the European farming areas of Kenya, while others of considerable promise have reached an advanced stage in the experiments. The following list outlines the position.

Grasses in agricultural practice. Commercial seed supplies available
Chloris gayana, Rhodes Grass, Nzoia Strain (Kenya). *Figures 1* and *2*.
Melinis minutiflora, Molasses Grass
Bromus marginatus

Good seed producers. Apparently valuable for temporary pasture. Require further trial for persistence under grazing
Cenchrus ciliaris, African Foxtail, two Kenya ecotypes. *Figure 3*
Chloris gayana, Rhodes Grass, Alego Strain (Kenya)
Melinis minutiflora, Molasses Grass, Chania Strain (Kenya)
Setaria sphacelata, ex-Nandi, Kenya
Bothriochloa insculpta, Sweet Pitted Grass
Pennisetum stramineum. *Figure 4*

Available only for vegetative propagation
Cynodon plectostachyum, Naivasha Star Grass
Cynodon dactylon, Common Star Grass
Brachiaria brizantha, Palisade Grass
Brachiaria soluta, Minor Palisade Grass
Panicum maximum, Guinea Grass
Panicum coloratum var. *makarikariensis*, Makarikari Grass

The references to ' strains ' in the above list concern material increased from small quantities of seed of natural strains. Such material has shown a high degree of uniformity in appearance, with marked differences between ecotypic groups of a species.

The three grasses in the first section of the list are already in fairly extensive use in the European farming areas of Kenya. They are the only pasture grasses of which a commercial seed supply has yet been produced in East Africa. Nzoia Rhodes grass, which has been proved markedly more persistent under intensive management than the former commercial variety developed in Queensland (EDWARDS, 1943), is successful throughout the Low Tree–High Grass vegetation which is one of the two great plant communities forming the agricultural region of Kenya. Molasses grass is suitable to use as temporary pasture in the moister part of this same community and also to some extent in the coastal belt, while *Bromus marginatus* has served for the early development of sown pasture in the area of the other major community of the region, Highland Grassland and Forest. In this latter vegetational area *Bromus*, which is an introduced grass of sub-tropical origin, will doubtless be superseded by more persistent indigenous grasses in due course. Also, species such as Cocksfoot (*Dactylis glomerata*) and the Rye grasses (*Lolium perenne* and *L. italicum*), of temperate origin, have given promise in limited parts of the Highland Grassland region, upwards of

Figure 1. Chloris gayana. *The Nzoia strain at Kabete, Kenya, 1950*

Figure 2. Combine-harvesting seed from a 100 acre block of Nzoia strain of Rhodes grass, Thika, Kenya, 1952

Figure 3. Cenchrus ciliaris (*African Foxtail*) *at Kabete, Kenya, 1949*

Figure 4. Pennisetum stramineum *at Kabete, Kenya, 1949*

8,000 ft. altitude, but these grasses are still in the experimental stage and they have not attained importance in practice.

Sufficient experience has been gained of the grasses in the second group of the list to indicate that they are likely to take an important part in future development, but they have not yet reached the stage of bulk production for distribution. With the possible exception of the ecotype of *Setaria sphacelata*, they are all adapted for use in the region of the Low Tree–High Grass vegetation at intermediate altitudes, and they will not succeed in the higher agricultural region discussed above. The need for more intensive study of the flora of this latter type is indicated, with trials of the promising indigenous species obtained, at a station situated within the ecological region. Such a station has recently been established in Kenya.

The grasses of the third group are in most cases valuable constituents of natural grassland, but their possibilities as temporary pasture in the arable rotation are limited by poor seeding qualities. Makarikari grass, derived from Southern Rhodesia, shows marked drought resistance in addition to a high degree of palatability, and it might well have proved an important factor in both African and European farming had it not fallen short in the matter of seed production. However, as has already been suggested, planted grasses might continue to play a part in the development of African agriculture, in view of small holdings and a plentiful labour supply. Also, there is the possibility that selective breeding for seeding qualities might eventually widen the scope of these and other valuable grasses.

In this brief account of the agricultural grasses of East Africa, mention should be made of two widely known, local species which have found a place in the development of several countries of the tropics and sub-tropics, and which are important in parts of the region under consideration. These are Kikuyu grass (*Pennisetum clandestinum*), indigenous to the high-altitude areas, and Elephant grass (*Pennisetum purpureum*), which follows the clearance of rain forest in parts of Uganda and is widely distributed at stream margins throughout the moister parts of East Africa. Kikuyu grass spreads by means of surface creeping stems and rhizomes, forming dense, leafy herbage. It appears in the highland region as a phase of the plant succession following the clearance of forest, much in the manner of Elephant grass in Uganda, and it can be maintained as productive pasture under intensive grazing management. It is not, however, suited to the purposes of alternate husbandry since its underground stems result in extreme difficulty of eradication. Elephant grass is under trial as temporary pasture in the area of its natural occurrence in Uganda, although this tall grass is more generally used as a source of reserve fodder for ensilage. Neither of these two grasses can be established on a practical scale from seed, but both can readily be planted from stem cuttings; in the case if Kikuyu grass, both stolons and rhizomes provide material for this purpose.

The intention of the present discussion is to deal with the grasses which have recently influenced the agricultural development of East Africa or which are likely to do so in the future. It should be appreciated, however, that non-graminaceous plants enter into the general picture of pasture development to an even greater extent than they do in the practice of temperate countries. Particularly in the drier pastoral areas of East Africa,

shrubs and trees constitute important sources of fodder, while in the present conditions of grazing management of other areas many of the woody plants are browsed to some extent. Some of the grasses under review are already being used in conjunction with pasture legumes, and development in this direction will follow and enhance the value of properly managed temporary grass. Experience again shows that suitable legumes should be sought mainly in the indigenous flora, although Lucerne (*Medicago sativa*), the only exotic which has given more than brief initial promise in mixture with grasses, is at present in use. Many legumes worthy of trial are to be found in the moister vegetational regions, and several true clovers occur in the highland areas. The most important of these is, so far, *Trifolium johnstoni* (EDWARDS and BOGDAN, 1951, p. 96), which tends to appear spontaneously in closely grazed herbage anywhere within its somewhat restricted climatic region. Of the many other species subjected to trial, recent work has shown *Glycine javanica*, a widely distributed, trailing legume, to be capable of withstanding intensive management when in mixture with grass.

THE PRESENT POSITION

When it is appreciated that development in East Africa has only in the past few decades emerged from the initial pioneer stage and that, apart from the highland areas of European settlement, primitive African peoples are mainly concerned, it is not surprising that the introduction of advanced agricultural practice is fraught with considerable difficulty. It is, in fact, well to recall that even in the older agricultural countries of Europe, the importance of temporary pasture as a constituent part of the arable rotation has been fully appreciated only within comparatively recent times.

Despite the fact that in East Africa the correct management of vast areas of natural grassland, in order to preserve a balance between utilization and deterioration, will always remain an important consideration, particularly in the drier regions, it is the use of artificially established grass in the limited crop-production areas which provides the key to agricultural progress. The attainment of this advance appears to offer the only possibility of checking the alarmingly rapid soil deterioration which is taking place in these areas upon which future development must largely be based. The use of sown or planted pasture presupposes a standard of farming which provides for suitable intensive management. This standard exists to only a limited extent in the European settlement areas, while in the African lands progress is dependent upon a radical change from the existing primitive methods of utilization. In Kenya encouraging progress has been made recently amongst European farmers, and the three grasses (mentioned above) of which commercial seed supplies have been produced, are in considerable demand. Also, in one area of the Rift Valley a further ecotype of Rhodes grass is harvested locally for ley establishment. The chief obstacle to this development in the European areas is the cost of converting the usually extensive holdings to intensive management, which involves considerable outlay in fencing and the introduction of methods of closer control. In the native agricultural areas, two main difficulties stand in the way of desirable reform. These are the existing systems of inheritance which result in excessive fragmentation of land and the necessity for progress towards higher living

standards, which may be expected to induce better appreciation of improved methods and also permit the cost of these to be met. The use of temporary grass leys is spreading amongst the African farmers of Uganda where considerable wealth is derived from cash crops such as cotton and coffee, and notable progress has been made in a part of Kenya. Recent development of such crops in the African areas of the latter country will probably have an important effect in preparing the way for improvement, and it is not unreasonable to hope that steps which must result from the present political upheaval in Kenya will be instrumental in breaking down the obstacle of complicated land inheritance, which obstructs proper utilization in a part of the moist highland region occupied by the Kikuyu people, and this may well point the way to improvement in the regions of other agricultural tribes.

The present position is that several grasses have been proved for the purpose of alternate husbandry in East Africa and they have been successfully introduced to practice in the three territories, although as yet to a limited extent. Also, numerous species of the indigenous flora give promise of value for this purpose, and investigation in this direction is proceeding. It is evident, however, that the greatest difficulty lies in effecting a general advance in agricultural method in order to create conditions under which temporary pasture can be effectively used. The European areas, where more advanced farming already exists, may be regarded as a useful field for demonstration, but even here, apart from the costly reorganization which is required, a much better understanding of the potentialities and use of temporary pasture is needed. Finally, the view has been expressed that practical advance will only be attained if the desirable pasture plants can be made available in the form of commercial seed supplies. Efforts to develop in this direction have been retarded in Kenya by failure to establish a system of seed certification. This should be accepted as a necessary step, so that selected material which has resulted from work over long periods can be insured against the detrimental effects of the present loose methods of production outside the Government controlled schemes.

(*Received April 1954*)

REFERENCES

EDWARDS, D. C. (1951). 'The Vegetation in Relation to Soil and Water Conservation in East Africa', *Bull. Commonw. Bur. Past.*, 41, 28–43

— and BOGDAN, A. V. (1951). 'Important Grassland Plants of Kenya', Sir Isaac Pitman and Sons, Ltd., London

MARTIN, W. S. (1944). 'Grass Covers in Relation to Soil Structure', *Emp. J. exp. Agric.*, **12,** 21–32

EDWARDS, D. C. (1943). 'The Nzoia Type of Rhodes Grass (*Chloris gayana*) for Temporary Leys', *E. Afr. agric. J.*, **9,** 62–68

The Teaching of Tropical Agriculture in Europe—III: France

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ORGANIZATION IN THE FRENCH UNION

In order to make clear the role of the various French institutions, it may be useful to set out first the general organization for teaching tropical agriculture in the French Union. This is summarized in the following table.

Level of basic education	*Institutions in France*	*Institutions in overseas territories*	*Posts for which training qualifies*
Higher Education (third grade): universities, special schools	École Supérieure d'Application d'Agriculture Tropicale		Agronomists, plantation managers
	Office de la Recherche Scientifique et Technique d'Outre-Mer	—	Specialists in agricultural research
Higher Education (second grade): schools of agriculture and horticulture, university institutes	Cycle d'Enseignement d'Agriculture Tropicale	—	Assistant agronomists, plantation assistants
Secondary Education: French regional schools of agriculture (1st baccalauréat)	Cycle d'Enseignement pratique de Modernisation Rurale Tropicale	Higher schools of agriculture in overseas territories	Overseers, assistants, foremen
Middle Secondary Education	—	Agricultural colleges	Inspectors, laboratory assistants
Higher Primary Education	—	Schools of practical agriculture	Field agents, instructors
Elementary Primary Education	—	Apprenticeship centres	Improved farmers

From this it is seen that there are no overseas centres giving instruction at the university level (the only one which has existed being the Higher School of Agriculture of Indo-China, which has unfortunately lapsed since the war). All higher education both for Frenchmen and overseas students is therefore given by institutions in France:

The École Supérieure d'Application d'Agriculture Tropicale (E.S.A.A.T.)

The Office de la Recherche Scientifique et Technique d'Outre-Mer (O.R.S.T.O.M.)

The Cycle d'Enseignement d'Agriculture Tropicale (C.E.A.T.). There exist on a similar plan, for rural engineering, for animal production, and for forestry, arrangements for tropical specialization which are provided by:

The tropical section of the National School of Rural Engineering

The Institute of Animal Husbandry and Veterinary Medicine of Tropical Countries (attached to the National Veterinary School at Alfort)

The tropical section of the National School of Waters and Forests at Nancy, and the courses of the Technical Centre for Tropical Forestry at Nogent.

THE 'ÉCOLE SUPÉRIEURE D'APPLICATION D'AGRICULTURE TROPICALE'

This institution, which was founded in 1902, was organized on its present basis in 1946 (Decree of 11 April 1946, modified by that of 10 November 1947). It is responsible to the Directorate of Agriculture, Livestock and Forests in the Ministry of Overseas France. It is situated at Paris in the premises of the Museum of Overseas France (293 Avenue Daumesnil). But these premises, which are not adequate to its needs, are to be replaced in the near future by a specially-designed building comprising the lecture theatres, laboratories, class-rooms and library which are needed. The role of the School is to prepare for tropical careers students who have already completed their education in general agriculture or science.

Tropical agriculture does not differ fundamentally from that of other regions and is based upon the same principles, which merely have to be adapted to the crops, conditions of soil and climate, and systems of farming. The training at E.S.A.A.T. is therefore only a complementary specialization. This specialization, however, covers a vast field which requires the services of distinct categories of technicians and scientists. For this reason the School is divided into two sections:

(1) *The Section of Agricultural Production*, which trains general agronomists qualified for the management of plantations, for the technical agricultural services, and for organizations concerned with the economic and social development of rural populations.

(2) *The Section of Agricultural Research*, which trains specialists for scientific work at research centres and government experiment stations, for private institutions which specialize in the study of major crops (Oils and Fats Institute, Fruit and Citrus Institute, Cotton and Textile Research Institute, Rubber Institute), and for the research services of the great organizations for colonization and development (Niger Office, General Company of Tropical Oils, *etc*).

The School receives as students: probationer agronomists of the Agricultural Service, regular French students, regular foreign students, and special students. The probationer agronomists are the future technicians of the Agricultural Service and the Agricultural Research Service, recruited by the Ministry of Overseas France. Their number varies from one year to another according to the demands of the territories. Qualifications for

admission are governed by the regulations which lay down conditions for these services. They correspond closely to those required of regular students at the School. Regular French students are admitted on their degrees but with reference also to the class of degree and to reports from their previous educational establishment. The qualifying degrees for admission to the School are:

For the Section of Agricultural Production:

'Ingénieurs agronomes' of the National Institute of Agronomy, and third-year students of this Institute (who in this case take their third year of 'applied' study at E.S.A.A.T.).

Diplomates of the Polytechnic School.

'Ingénieurs agronomes' with diplomas from the National Schools of Agriculture (at Grignon, Rennes, Montpellier and Algiers).

Diplomates of the Colonial School at Tunis, provided they have graduated in natural science.

For the Section of Agricultural Research:

The same qualifications as above, with the addition for relevant courses of:

Graduates in natural science who have not had training in agriculture.

Diplomates of the Central School of Arts and Manufactures, the National Higher Schools of Mines at Paris and St. Etienne, and the School of Industrial Physics and Chemistry of the City of Paris. Diplomates in pharmacy.

Diplomates of the National School of Agricultural Industries.

Regular foreign students are admitted to the two sections if they hold the qualifying French degrees or foreign degrees officially recognized as equivalent, or judged adequate by the Ministry of Overseas France. These candidates must be recommended by the representative of their country in France. Their applications should be sent through the office of this representative to the Ministry of Overseas France and should be accompanied by certificates of the qualifying degrees.

Special students, both French or foreign, are admitted to the extent of places available on the decision of the Director of the School, either to take a complete course or part of it.

For students who wish to make a deeper study of particular problems, the School can arrange special programmes which may include courses or periods at other educational or research institutions.

Syllabus of Studies

The School has no teaching staff of its own. It obtains the services, for different subjects, of highly qualified persons on the staff of the Ministry of Overseas France or of the great institutions of higher education, of scientific research, or of economics, which interest themselves in the problems of tropical regions.

The syllabus starts with instruction which is common to both sections on the tropical environment, conditions of tropical agriculture, experimental methods and the application of basic science to the tropical crops. It is

essential that research workers, whatever their fields of specialization, should have a general knowledge of these questions in order to remain in contact later with the realities of agriculture and not lose sight of the practical aims of their work. It is for this reason that future members of O.R.S.T.O.M., who will be working in sciences connected with agriculture, are also required to attend this common instruction. This conjunction of field and research workers at the first stage has the further advantage of forming bonds between those who will be engaged on the same task.

Thereafter the two sections are completely separated. The production section pursues its instruction by lectures and practical work on the tropical crops, methods of working in rural environments, economic and financial questions—in short, on all that has a bearing on the development of production and improvement of conditions among rural populations. These studies last for a year and are entirely carried out at the School in Paris. They are completed by visits to other institutions and by lectures from visitors. It is intended to prolong them by a second year spent in typical tropical areas in Senegal, the French Sudan, and the Ivory Coast, and occupied by demonstrational courses, practical work, and periods at research centres, establishments of the technical services, and plantations.

The students of the agricultural research section are transferred, after the common instruction, to the Office de la Recherche Scientifique et Technique d'Outre-Mer (which will be described in more detail below), by whom they are given further instruction in the following subjects: soil science, genetics, plant physiology, botany, phytopathology, agricultural entomology, plant biochemistry, and technology. These studies last for two years.

Tropical agriculture is such a vast subject that obviously it is impossible in one year to go deeply into all its aspects. The sole object is to give the students a sufficient basis for them to be able to adapt their knowledge to the crops, farming methods and conditions of the regions in which they are called upon to serve. Without going into details of the courses, the following summary of their content may be given.

The course on *Physical Geography* comprises a general part covering the special characteristics of tropical regions due to climate, geology, orography and hydrography; and a special part dealing in more detail with the territories of the French Union.

The course on *Meteorology and Climatic Ecology* by M. P. Carton, honorary Inspector-General of Agriculture, member of the Academy of Colonial Sciences, and author of works on the climate of Indo-China and on agricultural climatology, deals first with principles of dynamic meteorology and climatology with reference to the tropics, the action of environmental factors on plants, and the combined action of climate and vegetation on the soil. It then proceeds with the ecology of cultivated plants, the idea of critical periods, climatic equivalents and the methods of observation used in this science. It next examines the influence of climate on diseases and pests of plants, and ends with the connection of ecology with animal production and human life.

The course on *Soils of Tropical Regions*, by Professor G. Aubert, Director of the Soil Service of O.R.S.T.O.M., is an introduction to tropical soils both

for future soil scientists and for agronomists who will be concerned with production from the soil.

In his course on *Plant Geography and Nature Conservation*, M. Humbert, professor at the Natural History Museum, deals with the distribution of species, plant communities, primary and secondary vegetation in tropical climates, the destruction of vegetation (including the important question of bush fires), and the economic and social consequences of destroying the vegetation cover.

A course on *Human Hygiene* is given by Dr. Girard, member of the Academy of Colonial Sciences and principal officer of the Institut Pasteur at Paris.

The very important course on *Methods of Research and Experimentation in Tropical Agronomy* is divided into two parts. The first, on objectives and methods, is entrusted to Professor Boeuf, member of the Academy of Agriculture, and Director of the Genetics Centre of O.R.S.T.O.M., whose research work on the improvement of cereals in North Africa and on general problems of genetics is well known. He deals with experimental technique in genetics, experiments on soils and fertilizers, acclimatization, pest and disease control, *etc* and ends with methods of statistical survey and the estimation of yields and acreages. The second part, on the interpretation of results, is given by M. Vessereau, a specialist on statistical analysis, who covers methods of mathematical statistics and their application to biometry, genetics and agricultural experiments.

This course is completed by exercises on the most common experimental lay-outs and their statistical interpretation (randomized blocks, Latin squares, replication at several places or over several seasons) and on calculations of correlation co-efficients and their significance.

Advanced Plant Physiology, by M. P. Chouard, member of the Academy of Agriculture, professor at the Sorbonne, covers modern findings of physiology on stimulatory factors, growth and development regulators, factors causing floral development and factors of dormancy and inhibition. He deals with auxins and other plant hormones and their action on plant life, together with that of anti-hormones. Professor Chouard's own work is in the forefront of our knowledge on these subjects.

The course on *Advanced Plant Biology* is given by Professor Noachovitch, member of the Higher Council of Agriculture, and lecturer at the Institute of Agronomy. One of the objects of this course is to initiate future scientists into the formation and localization of plant substances, such as starch, wax, gums, latex, resin and essential oils, and into the methods of rigorous identification of these substances. The same professor lectures on *Advanced Genetics and Improvement of the Principal Tropical Crops* and illustrates his lectures particularly from four crops on which much work has been done: rice, sugar cane, cotton and maize. These courses are accompanied by laboratory work.

Advanced Biochemistry is taught by M. Lavollay, professor at the 'Conservatoire National des Arts et Métiers', and by M. Bui-Xuan-Nhuan, principal technological officer at the Cotton and Textile Research Institute. They deal with the chemical changes during processing of tropical crops, and with the principles of nutrition (calorific value of foods, starch equivalents, vitamins, minerals and formulation of rations).

The course on *Rural Engineering in the Tropics* is entrusted to M. Rossin, chief engineer of the ' Génie Rurale ', Director of Agriculture, Livestock and Forests at the Ministry of Overseas France, who early in his career carried out important engineering works for the Niger Office, and has studied comparable large foreign schemes, especially those of the Anglo-Egyptian Sudan. His lectures cover irrigation, drainage, rural building and mechanization among other subjects.

Organization of Agricultural Production is taught by M. M. Guillaume, Inspector-General of Agriculture, and embraces tropical farming systems, economic and social obstacles, the role of government services, extension work, food supplies, land tenure, soil conservation, the organization of markets, and development plans.

A course on *Agricultural and Pastoral Ecology of Tropical Countries* is given by M. R. Portères, professor at the Natural History Museum. Besides lectures on the general aspects, he illustrates his theme from the coffee crop, studying the action of moisture, temperature and length of day on floral differentiation, and the ecological relations between the activity of root, shoot and flowers.

In *Systematic Botany*, Professor Pellegrin, honorary deputy director of the Natural History Museum, gives lectures accompanied by practical work. *Comparative Agriculture of Tropical Countries* is taught by M. Dumont, professor at the National Institute of Agronomy, who has made studies in Europe, America, Asia and Africa. *Plantation Management* is the subject of M. Ferrand, Director of the research centre of the Oils and Fats Research Institute and technical adviser to the French Rubber Institute. He deals particularly with choice of location, clearing work, establishment and soil management in plantations.

The course on *Plant Pathology*, by M. Maublanc, professor emeritus at the National Institute of Agronomy, is accompanied by practical work, as is also that on *Agricultural Entomology* by M. P. Vayssière, professor at the Natural History Museum, who pays particular attention to locust control and deals also with modern insecticidal equipment. A course on *Forest Economy* is given by M. Marcon, Director-General of the Technical Centre for Tropical Forestry, and one on *Animal Husbandry and Veterinary Hygiene* by Professor Létard and M. Larrat.

It is not possible to give details here of the courses on *Special Agriculture* which cover the principal tropical crops and are given by experts with long practical experience. A course on *Technology of Agricultural Products* covers the processing and industrial utilization of oilseeds, starches, spices, *etc.* In *The Standardization of Tropical Plant Products and Their Commercial Preparation*, Professor Noachovitch deals also with the grading and inspection of these products and the objectives of such bodies as the ' Association Française de Normalisation ' and the ' Organisation Internationale de Normalisation '.

A course on *The Administration and Finances of French Overseas Territories* is given by Inspector-General Lebègue, and one on *Economic Geography and Political Economy of the French Union* by Inspector-General Gayet. In the economic field M. Baumont, professor at the ' Conservatoire National des Arts et Métiers ', lectures on *International Economics*, discussing the place of the tropical territories of the French Union in the world economy, recent

economic history, and the principal foreign economies—the United States, Great Britain and Russia. M. Cramois, Director-General of the 'Caisse National de Crédit Agricole', undertakes *Questions of Credit and Accounting* in their relation to plantation, peasant and co-operative agriculture.

In addition to these courses, the School each year arranges lectures by distinguished French or foreign visitors on subjects of direct or indirect interest to agricultural developments in the tropics: studies in ethnography, economics, botany, zoology, climatology, reports of missions carried out in the territories or abroad, *etc.*

The syllabus is rounded off by visits to various scientific institutions or industrial establishments and by a study journey to the South of France and North Africa.

THE 'CYCLE D'ENSEIGNEMENT D'AGRICULTURE TROPICALE'

As we have seen above, the courses at E.S.A.A.T. can only be followed by students who have already obtained a qualification from a university or technical institute of higher education. But the tropical regions of the French Union also need technicians with lesser academic qualifications. It has therefore been necessary to provide for them a suitable training in the 'Cycle d'Enseignement d'Agriculture Tropicale'. As in the case of E.S.A.A.T., this is intended to be only a supplementary initiation into the tropical crops and conditions of tropical agriculture for students who have already received a grounding in general agriculture.

The institutions which, in France, qualify students for admission to C.E.A.T. are:

The Colonial School of Agriculture of Tunis.
The National School of Horticulture at Versailles.
The University Agricultural Institutes at Toulouse and Nancy.
The Agricultural Institute at Beauvais.
The Higher Schools of Agriculture at Angers and Purpan-Toulouse.
The Technical Institute of Practical Agriculture at Paris.

Diplomates of the first two are admitted on their diplomas; the others have to sit an examination which is held each year in Paris about the 20th of September.

Foreigners can be accepted as regular students if they hold qualifications which are officially recognized as equivalent or which are judged to be adequate by the Director of Agriculture, Livestock and Forests at the Ministry of Overseas France. Applications must be made through the representative of their government in France as for E.S.A.A.T.

Special students, French or foreign, can be admitted to the extent of places available, to take the whole or part of the courses if the Director considers their previous training to qualify them.

The course of instruction, which lasts for a year, is divided into two parts. The first, from October to April, is theoretical, and is given at E.S.A.A.T. The students follow parts of the School's syllabus and other courses and exercises which are specially designed for them. The contents include general principles of agriculture, land use, extension work among rural populations, the major crops, plantation management, basic principles

of plant protection (plant pathology and agricultural entomology), organization and use of agricultural credit, methods of assistance to tropical peasants, *etc.* Lectures occupy 247 sessions of one-and-a-half hours each, and practical work 22 periods of three hours.

The second period, from April to July, is devoted to special subjects which may include agricultural mechanization, the preparation and inspection of agricultural products, crop protection and more especially locust control, credit and co-operation, rice cultivation, development schemes (secteurs de modernisation) in North Africa, *etc.*

THE 'OFFICE DE LA RECHERCHE SCIENTIFIQUE ET TECHNIQUE D'OUTRE-MER'

This organization, founded in 1943, is an autonomous public body receiving its authority from the Ministry of Overseas France. It is administered by a governing body comprising, as well as persons distinguished in science and economics, the directors of the principal services at the Ministry (Agriculture, Livestock and Forests; Economic Affairs; Health; Education; Public Works). It has been directed since its foundation by M. R. Combes, member of the Institute, professor of the Faculty of Sciences at Paris. The Director's office and secretariat are in Paris (20 Rue Monsieur).

The function of the Office is to promote, guide, co-ordinate and control scientific and technical research in the overseas territories. Its programme is limited to basic research in the natural sciences and to the training of research workers for this function. The research and educational establishments which it set up in 1945 and 1952 in France and in the territories are amongst the finest scientific and cultural foundations of this period.

The principal subjects studied in these institutions are:

Soil science.
Plant breeding, plant pathology, plant physiology, botany.
Agricultural, medical and veterinary entomology.
Geophysics.
Geology.
Freshwater hydrology.
Biological and physical oceanography.

Since 1953, the sphere of action of the Office has been extended by the attachment to it of agricultural research organizations which were previously under the directorate of Agriculture, Livestock and Forests in the Ministry of Overseas France or under the Inspectors-General of Agriculture in the territories.

The complete organization of O.R.S.T.O.M. is at present as follows:

At Headquarters in Paris

Directorate, secretariat (general and scientific), central library, publications branch.

Scientific Research Services

Institutes of education and research at Bondy (near Paris) and Adiopodoumé (Ivory Coast).
Geophysics Centre at M'Bour (Senegal).
Soil Science Centre at Dakar-Hann (Senegal).

Agricultural Research

Central services comprising (1) section for study by subjects, (2) section for study by crops or groups of crops at Nogent-sur-Marne (near Paris).
Agricultural Research Centre for the Sudan region at M'Bambey (Senegal).
Agricultural Research Centre for the coastal region at Bingerville (Ivory Coast).
Cinchona Station at Sérédou (Guinea).
Central Agricultural Station of Bukoko (Ubangi-Chari).
Agricultural Research Service of Madagascar at Lake Alaotra.
Agricultural Research Laboratory of the Cameroons at N'Kongsamba.
And experimental stations which are dependent on these institutions.

Affiliated

Scientific Research Institute of Madagascar at Tananarive.
Institute of Central African Studies at Brazzaville (Middle Congo).
French Institute of Oceania at Nouméa (New Caledonia).
Research Institute of the Cameroons at Yaoundé.
French Institute of Central America at Cayenne (Guiana).
Research Institute of Togoland at Lomé.

Training of Agricultural Research Specialists

O.R.S.T.O.M. does not only train research workers for its own establishments and for those which are concerned with agricultural research, but also for employment by other scientific and technical organizations. Students who are specializing in subjects connected with agriculture, and who are generally, as we have seen, pupils of the research section of E.S.A.A.T., follow the O.R.S.T.O.M. courses under the same conditions as other students.

The instruction is given by the scientific staff of the Office and is arranged for each student according to the subjects and the work for which he is destined. The studies last for two years. Chemists and technologists are trained in the agricultural research laboratories at Nogent-sur-Marne, and soil scientists, geneticists, botanists, plant physiologists, plant pathologists and entomologists at the Institutes of Education and Research at Bondy and Adiopodoumé.

The Institute at Bondy, in the suburbs of Paris, possesses well equipped modern laboratories, experimental plots and glasshouses for tropical crops. It is under the direction of Professor F. Boeuf, member of the Academy of Agriculture ; the deputy director is M. G. Aubert, soil scientist, chief of the soils service. The scientific staff includes two pedologists, two soil chemists, two microbiologists, three geneticists, two entomologists and one plant pathologist. The students at Bondy take a basic training which comprises lectures, laboratory work and practical exercises. They can also, if their special subject requires it, attend lectures at other institutions such as the Natural History Museum, the Sorbonne, the National Agricultural Research Institute, *etc.*

The Institute at Adiopodoumé, where the students pass their second year, has the function of completing their training in a tropical environment and in contact with the realities of their future work. Situated 18 km. from

Abidjan on the Ivory Coast, the Institute has 250 hectares of land overlooking the Ebrie lagoon in an area typical of the rain-forest zone. It has two large buildings, laboratories well equipped for teaching and research, and special installations (controlled temperature rooms, sterile rooms, *etc*). To allow for individual work by scientists attached to the centre, certain laboratories are divided into cubicles. The equipment of the laboratories, which is already of a very high standard, allows the use of all the techniques of morphology, cytology, biochemistry and microbiology. The accommodation allows working space for about 40 scientists and is amongst the best possessed by France for work in plant biology and agronomy.

The Institute at Adiopodoumé, under the direction of M. G. Mangenot, professor of the Sorbonne, comprises the following sections and sectional directors:

Botany (M. Mangenot)
Genetics and crops (M. J. Miège)
Plant pathology (M. J. Chevaugeon)
Applied entomology (M. P. Cachan)
Medical entomology (Dr. J. Doucet)
Plant physiology (M. Jacquemin)
Soil science (under the supervision of Prof. Aubert).

During the course of their stay at Adiopodoumé the students work in the laboratories or on the experimental plots and make study tours in the interior of the country.

Housing facilities correspond to the numbers which the laboratory accommodates. They include a hostel with 30 rooms, a dining hall and games room, which accommodates the annual students and visiting research workers. There are also official houses for the Director and members of the scientific and administrative staff.

Foreign students taking the agricultural research course of E.S.A.A.T. spend a year, like the French students, at Adiopodoumé. The Institute also accepts foreign students or research workers who wish to work on particular problems. Special arrangements to this end have already been made with certain foreign countries. The Swiss Government has established a ' Federal Research Centre on the Ivory Coast ' which comprises a small laboratory and a hostel. The Dutch Government has also requested permission to build a hostel for its research workers who may be working in the laboratories of the Institute.

(*Received April 1954*)

Aggregate Stability in a Clay Soil in Relation to Cacao Cultivation

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INTRODUCTION

In a previous paper (Wasowicz, 1952), it was noted that cacao grown in pots in a silty-clay soil* gave better growth and larger responses to fertilizer applications than did cacao grown in a sandy-loam soil†, whereas in the field the latter soil is known to have a higher productivity status and generally to support the larger crops of cacao. This difference was attributed to the way in which the soil was prepared for the pot experiment. The silty-clay soil as brought from the field was in large clods; these were thoroughly air-dried, broken into smaller aggregates, and sieved to separate the $\frac{1}{4}$ in.–$\frac{1}{2}$ in. fraction. This fraction was further air-dried and used to fill the pots. The sandy-loam soil was simply air-dried, passed through a $\frac{1}{2}$ in. sieve, and filled into the pots, and in this condition appeared to have a good aggregate structure. Under constant watering, the sandy-loam soil aggregates quickly disintegrated to form a fine-grained mass, whereas the silty-clay aggregates persisted, so that the soil retained a well drained and well aerated structure, and supported better growth of cacao and gave a larger response to fertilizers. It was therefore decided to investigate further the aggregate structure of the silty-clay soil.

The experiment to be described has already been the subject of a preliminary note (Havord, 1953).

METHODS AND MATERIALS

A large sample of the same silty-clay soil used in the preliminary test was air-dried, broken into lumps, sun-dried, and fractionally sieved. Pots were filled with aggregates of the following sizes: (*i*) Less than 1 mm (*ii*) 2–4 mm (*iii*) 4–12 mm. In addition, further pots were filled with the 4–12 mm aggregates after these had been sprayed with (*iv*) a suspension of calcium hydroxide in water, and (*v*) ferrous sulphate solution, and subsequently dried in air.

It was thought that the last two treatments might result in further stabilization of the aggregates.

The pots were arranged in the greenhouse in a randomized block layout with four replications of the five treatments. Cacao seeds of known parentage (ICS 1 × ICS 6, obtained by hand pollination) were planted, three per pot. Each pot received 9 g of a mixture of equal parts of ammonium sulphate, sodium di-hydrogen phosphate and potassium chloride shortly after planting and again one month before sampling.

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*Sangre Grande Silty-Clay
†River Estate Sandy-Loam } (Chenery, 1952).

The cacao plants were grown for nine months with daily watering from a spray. Measurements of the height of the seedlings were then taken, and the plants subsequently sampled and the oven-dry weights of stems and roots determined. Leaf samples from each treatment were chemically analysed and, in addition, the product of the length and width of the first three fully hardened leaves in each pot was determined.

Before excavating the roots, the stems were cut off at the soil surface level and the rates of percolation of water through the pots determined.

EXPERIMENTAL RESULTS

Table 1. Effect of Treatments on Growth of Cacao Seedlings

Measurement	*Treatments*					*Least significant difference and level of significance*
	(i) Aggreg. < 1 *mm*	*(ii) Aggreg.* 2–4 *mm*	*(iii) Aggreg.* 4–12 *mm*	*(iv) Plus lime* 4–12 *mm*	*(v) Plus* $FeSO_4$ 4–12 *mm*	
Length of stem (cm)	40·0	52·2	49·7	55·9	53·4	8·0 at 1% 5·8 at 5%
Oven-dry weight of stem (g)	19.25	27·25	27·75	31·50	27·50	7·10 at 2% 8·23 at 1%
Oven-dry weight of roots (g)	11·07	17·27	17·30	19·40	17·45	6·58 at 0·1% 4·68 at 1%
Stem–root ratio	1·73	1·58	1·60	1·62	1·57	—
Product of leaf* length and width (cm^2)	90·0	110·4	107·4	110·1	102·1	Differences not significant

*Using the first three fully hardened leaves.

Table 1 gives data for growth measurements on the cacao seedlings, being means for four pots containing three seedlings per pot. The growth of stems and roots was considerably, and highly significantly, greater in the pots containing 2–4 mm and 4–12 mm aggregates than in those containing the smaller aggregates. Also the stem–root ratio was lower, indicating the greater relative extent of root development in the larger aggregates. Differences between treatments (*ii*), (*iii*), (*iv*) and (*v*) are not significant, although treatment (*iv*) (aggregate sprayed with calcium hydroxide solution) consistently gives higher growth values than the other treatments. This tendency may be due to the provision of calcium as a nutrient and the neutralizing effect of the lime on this highly acid base-deficient soil. Leaf size was smallest in the pots containing the smallest aggregates, although the differences fail to attain significance.

Figure 1 illustrates the differences in stem and leaf growth between treatments, and *Figure 2* shows the extent of root growth in the three sizes of aggregates. In addition to the decreased root development in the smaller-sized aggregates, there were marked differences in the form of root development. The seedlings grown in the 2–4 mm and 4–12 mm fractions developed thick and vigorous tap-roots, reaching the bottom of the pot. Many thick lateral roots also developed and were much branched, filling

Figure 1

A Aggregates less than 1 mm
B ,, 2–4 mm
C ,, 4–12 mm
D ,, 4–12 mm plus calcium hydroxide
E ,, 4–12 mm plus ferrous sulphate

Table 2. Chemical Composition of Leaves

	<1 mm	2–4 mm	4–12 mm	*Plus lime* 4–12 mm	*Plus* $FeSO_4$ 4–12 mm	
A Grams per 100 leaves						
Dry weight	23·2	33·6	30·4	35·2	33·9	
Organic matter	21·5	31·1	28·2	32·6	31·2	
Total ash	1·74	2·45	2·22	2·74	2·71	
Total N	0·62	0·88	0·82	0·95	0·97	
Total P_2O_5	0·15	0·21	0·21	0·24	0·19	
Total K_2O	0·66	0·90	0·88	1·04	0·91	
B Ash as per cent dry matter—Nutrients as per cent ash						*'Standard'**
Ash	7·48	7·30	7·30	7·77	8·00	7·46
N	35·6	35·9	36·9	34·7	35·8	30·8
P_2O_5	8·60	8·57	9·45	8·76	7·01	8·65
K_2O	37·9	36·7	39·6	38·0	33·6	33·9
C Nutrient ratio (per cent ash basis)						
N/P_2O_5	4·13	4·19	3·90	3·95	5·10	3·64
N/K_2O	0·94	0·98	0·93	0·91	1·06	0·88
K_2O/P_2O_5	4·40	4·28	4·19	4·33	4·79	4·13

*Standard values from mature tree receiving NPK fertilizers (HARDY, McDONALD and RODRIGUES, 1935).

the whole pot. When it is remembered that three of these root systems as shown in *Figure 2* developed in one pot 8 in. deep, the extent to which the root systems ramified throughout the soil is apparent. On the other hand, the seedlings grown in the 1–2 mm aggregates did not develop vigorous tap-

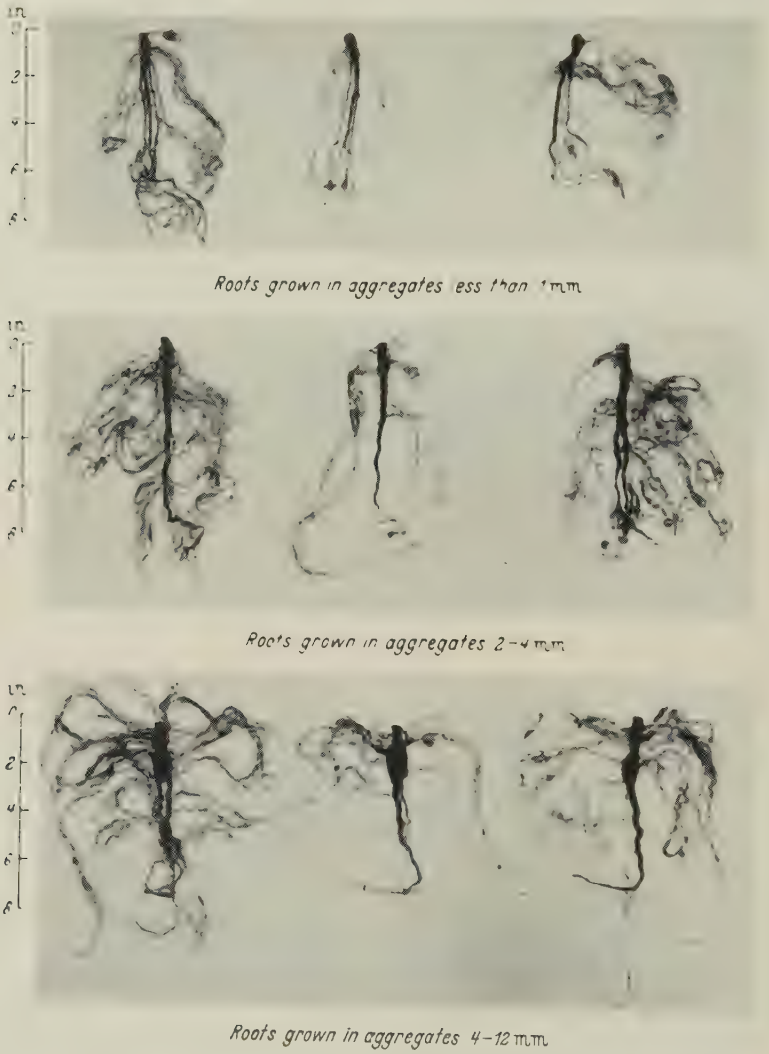

Figure 2

roots; the roots bifurcated several times in attempts to penetrate the soil, and produced several thin spindly roots which barely reached the bottom of the pots. Many of these were dead below a depth of 4 in. There were far fewer lateral roots, and most of them were confined to the top 2 in. of soil.

Despite daily watering, the soil did dry out sufficiently between waterings for some cracks to form in two of the pots containing the smallest sized

aggregates. Cracks did not develop in the pots containing the larger aggregates.

Figure 3 illustrates the influence of cracking on root development, showing two plants grown in the same pot, photographed in two planes at right-angles, along and across a crack respectively. The roots of the plant shown on the right gained access to a crack, whereas those of the plant on the left did not. The much increased root development, and the fact that the roots are largely confined to the crack, are readily apparent.

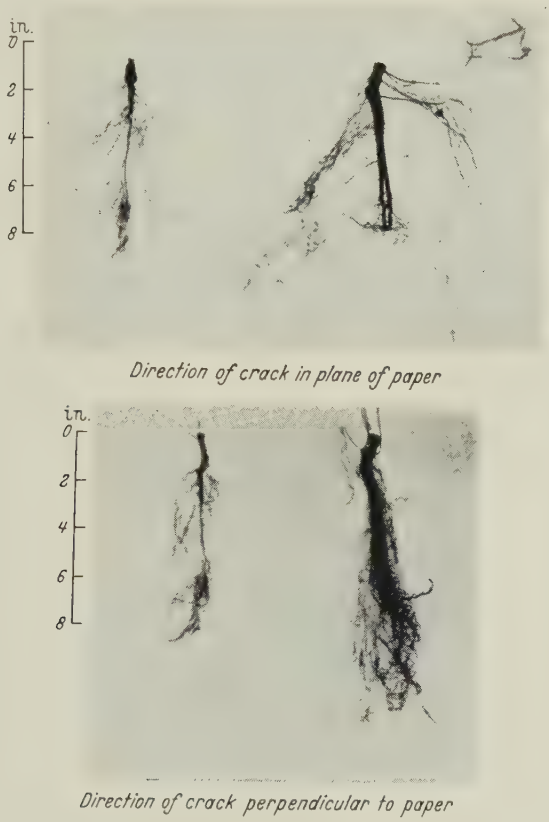

Figure 3. Roots grown in aggregates less than 1 mm, with access to a crack

The leaves taken for analysis were as nearly as could be judged of similar physiological ages, being newly hardened flushes as sampled by McDonald and Rodrigues (1934). Only one bulk sample from each treatment could be taken.

The uptake of nutrients expressed as grams per 100 leaves shows that the total uptake by the plants growing in the smaller-sized soil aggregates was much reduced in comparison with all others. There was little variation in leaf composition expressed as percentage ash, suggesting that the reduced

uptake of nutrients by the plant growing in the smaller aggregate resulted only in slower growth, and did not induce nutrient deficiencies or unbalance. There was a tendency for uptake of phosphorus and, to a lesser extent, of potassium to be depressed in the plants growing in aggregates sprayed with ferrous sulphate.

WATER PERMEABILITY OF SOIL IN POTS

In order to determine the rate of percolation of water through the soil at the end of the experiment, the pots were soaked for four days in a trough of water, gradually raising the water level until it coincided with the soil surface, thus displacing the soil-air. The pots were removed from the water and allowed to drain freely. A 3 in. diameter tube was inserted to a depth of half an inch into the soil surface in each pot and 500 ml of water poured as rapidly as possible into the tube. The times taken for the water to drain completely out of the tube are given in *Table 3.*

Table 3. Time Taken for Percolation of 500 cc of Water

< 1 *mm*	2–4 *mm*	4–12 *mm*	*Plus lime* 4–12 *mm*	*Plus* $FeSO_4$ 4–12 *mm*
		(*sec*)		
Approx. 200 ml after 3 hr	120	23	27	25
,, 250 cc after 3 hr	90	12	7	30
694 sec*	90	8	11	8
1590 sec*	60	6	14	12
Means	90 sec	12·25 sec	14·75 sec	18·75 sec

*Some cracks in these pots.

These results show that even after nine months of continued watering, there was very little structural deterioration in the pots containing the 2–4 mm and 4–12 mm aggregates. For the aggregates smaller than 1 mm, the faster rates marked with an asterisk show the effect of cracking on the percolation rate; as has already been noted, root development was enhanced by the cracking and was largely confined to the cracks. Apart from these cracks, the soil in the pots containing the smallest aggregates had amalgamated to form an amorphous mass, impervious to water. The percolation rate through the 4–12 mm aggregates was greater than that through the 2–4 mm aggregates, as would be expected if there had been little or no structural breakdown. However, the rate for the 2–4 mm aggregates is very rapid, approximating to 17 in./hr.

DISCUSSION

The experiment has shown that an aggregate structure suitable for satisfactory growth of cacao can be developed in this soil, and that if the aggregates are thoroughly dried they are remarkably water stable, and has emphasized the importance of a suitable structure for maximum growth of cacao seedlings.

Similar soils to that investigated are widespread in the Northern Plain of Trinidad and, as has been previously pointed out by Wasowicz (*loc.cit.*), these soils develop profuse cracks during the dry season. This has the effect of splitting the top few inches of the soil into large clods, and finer cracking within the clods produces a structure akin to an aggregate structure. If these structural units can be thoroughly dried during the dry season, and provided frequent efficient drains are provided to lead rain-water off through the cracks rapidly, the structure should persist long into or throughout the following wet season. In the absence of efficient drains, water may stagnate in the cracks and accelerate their closure. It has been frequently observed that, where frequent drains are present and are kept open, cracks do persist well into the wet season, and during the rains water may be seen pouring into the drains through cracks opening into the drain walls. The provision of frequent drains is, in fact, standard practice on estates on this type of soil, and in some cases it is carried to the stage where high beds have been developed between the drains by many years of constant deepening of the drains, using excavated soil to build the beds. However, owing to high present-day costs and shortages of labour, drains are often neglected and allowed to become blocked.

Another way of assisting the stabilization of an aggregate structure formed by cracking and drying would be by soil cultivation designed to shatter the soil into suitable aggregates. If this is done early in the dry season whilst the soil is still moist enough to cultivate but not so wet as to be too sticky, an aggregate structure should be formed and the aggregates should dry out and become stabilized during the latter part of the dry season. This treatment is regularly practised on sugar estates in Trinidad, and the importance of soil cracking in soils growing sugar cane has been emphasized by HARDY and DERRAUGH (1947). Soils growing cacao are never cultivated in Trinidad, although light forking has long been practised in Grenada. Cacao is normally largely a surface-rooting crop and the damage which might result from dry season cultivations may vitiate any structural improvements that might be obtained by cultivation. A promising technique may be deep sub-soiling and surface cultivation (*e.g.* rotary hoeing) to shatter the soil to considerable depth, carried out early in the dry season, and then allowing the soil to dry out, prior to planting cacao. In addition, graded beds carrying, say, two rows of cacao trees might be constructed immediately after the cultivations. Subsequently, inter-row surface cultivation such as rotary hoeing could be practised. Plans are in hand to try this treatment on this type of soil on the field experiment scale.

In this connection, it is interesting to note the results of a small-scale field experiment carried out by the authors on the same soil-type. Cacao was grown under four treatments, control (hand-weeding only), mulching, mulch *plus* fertilizers and hand-forking during the dry season. The treatments were arranged as a 4 × 4 latin square, and plots were split for cacao seedlings (ICS 1 × ICS 6) and cuttings (ICS 1). Seedlings were planted in September and cuttings in November 1951, and the forking treatment carried out in April 1952. Growth measurements were taken in October 1952. The only treatment to show any increased growth was the forking, even though the treatment had been carried out but once. Only the seedlings

responded to forking, there being no significant differences between growth measurements for cuttings. This may be accounted for by the differing root habits of seedlings and cuttings, the former tending to produce a vigorous tap-root earlier.

The figures for heights of the seedlings, in inches, were:

Control	Forking	Mulch	Mulch+Fertilizers	Significant difference (5 per cent)
22·6	25·1	22·6	20·6	2·43

It is generally believed by planters in Trinidad that a good cacao crop follows a 'dry' dry season and a 'not too wet' rainy season, and conversely that an 'excessively rainy' dry or wet season adversely affects the following crop. This has been ascribed to various causes, among them being less incidence of diseases such as Black Pod (*Phytophthora palmivora*, Butler) and Witches' Broom (*Marasmius perniciosus*, Stahel) during dry periods, or some physiological benefit that the cacao tree may derive from dry-season dormancy. It is suggested that enhanced soil cracking during the dry season and persistence of the structure thus formed well into the wet season may be an important contributory factor.

Dunlop (1925) studied the relationship between cacao yields in Trinidad and rainfall, and concluded that estates having an average annual rainfall lying between 70 and 75 in. were better suited for cacao growing than those with annual rainfalls over 80 in. For one estate he obtained a high negative correlation coefficient between the May and June rainfall and the amount of the subsequent crop, and also between the May rainfall and the subsequent crop. (The dry season in Trinidad extends from January to May.) Dunlop considered this remarkable, as the result refers to the rainfall of one month only and that six months before the bulk of the crop referred to is reaped. The fact is in harmony, however, with the suggestion that the effect of the amount of rainfall in the dry season is a powerful factor controlling subsequent cacao yields.

It is difficult to obtain reliable data enabling correlations to be made between crop yields since 1925 and rainfall, owing to other factors, such as the advent of Witches' Broom disease, the neglect occasioned by low cacao prices in the 1930's and, more especially, neglect occasioned by World War II, and the general decline in soil fertility, all of which have had a depressing influence on cacao production in Trinidad. However, yield figures for the same estate as that quoted in reference to Dunlop's work, and the general opinion of planters, do support the conclusions that cacao yields vary inversely with the amount of the preceding dry season rainfall.

Recent preliminary investigations have suggested that similar stabilization of aggregate structure by drying can occur even in a sandy-loam soil. In this case, rain-drop impact may quickly destroy the structure at the surface, forming a 'seal' or 'crust', and this seal may protect the soil beneath from the impact of rain so that the structure below may persist for a considerable time.

SUMMARY

A pot experiment is described in which cacao seedlings were grown in various sized, artificially prepared, aggregates of a silty-clay soil. The

deleterious effect of the smaller sized aggregates on the growth of cacao, and the great water stability of the larger aggregates after drying, were demonstrated. The practical implications of these findings in relation to soil management in cacao cultivation are discussed.

ACKNOWLEDGMENTS

Thanks are due to Professor F. Hardy for his continued interest and encouragement during this work.

(*Received February 1954*)

REFERENCES

CHENERY, E. M. (1952). 'The soils of Central Trinidad', Dept. of Agriculture, Trinidad

DUNLOP, W. R. (1925). 'Rainfall correlations in Trinidad', *Nature, Lond.*, **115**, 192

HARDY, F., and DERRAUGH, L. F. (1947). 'The water and air relations of some Trinidad sugar cane soils', *Trop. Agriculture, Trin.*, **24**, 76

— MCDONALD, J. A., and RODRIGUES, G. (1935). 'Leaf analysis as a means of diagnosing nutrient requirements of tropical orchard crops', *J. agric. Sci.*, **25**, 4, 610

HAVORD, G. (1953). 'Notes on soil investigations in progress', A Report on Cacao Research, 1952. I.C.T.A., Trinidad

MCDONALD, J. A., and RODRIGUES, G. (1934). 'The effect of manurial treatments on the chemical composition of cacao leaves', Fourth Ann. Rep. on Cacao Research, I.C.T.A., Trinidad, p. 75

WASOWICZ, T. E. (1952). 'Notes on the fertility of cacao soils', *Trop. Agriculture, Trin.*, **29**, 156

The Use of Pot Tests in Research on the Fertility of Sugar Cane Soils

Paper V: A Pot Test on the Relative Effectiveness of Forms and Placements of Phosphatic Fertilizers

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INTRODUCTION

Sugar cane was grown for three months as a soil exhauster and indicator plant in single kerosene tins in a pot test of Type 3 as described in Paper I of this series. The soil used (Cunupia clay) was of exactly the same batch of soil as was used in the experiment presented in Paper IV. The object of the experiment was to compare the relative effectiveness of mono-calcium, di-calcium and tri-calcium phosphate, when added in various ways to unlimed and limed portions of this acid phosphate-fixing soil. In order to make the comparison between the phosphate treatments as sensitive as possible, the low phosphate content of this soil had to be accentuated, as previous experimental results (Paper IV) proved that, providing root space is adequate, the 'available' phosphate present in this soil is almost sufficient to support a healthy cane crop. This was achieved by reducing the volume of soil for each cane plant to only 4 gal. (= 35 lb. air-dry soil) and maintaining vigorous growth of the cane during 14 weeks by means of optimum moisture and nutrients supply. The comparison between various phosphate treatments should be carried out at such a phosphate level that any change in effectiveness is reflected by yield response of the indicator plant. A preliminary trial was therefore carried out to ascertain the phosphate requirements of the cane plant under the conditions of the experiment. The results of this preliminary trial are first presented and briefly discussed below.

THE PRELIMINARY TEST

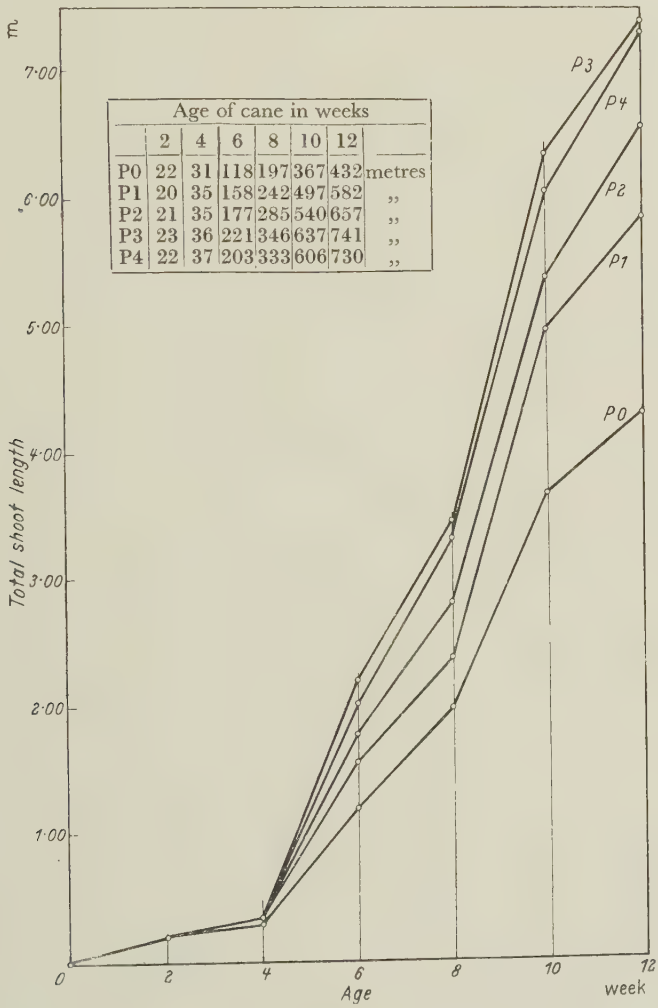
Experimental Procedure

This trial involved five dressings of mono-calcium phosphate, equivalent to dosages of: 0, $3\frac{3}{4}$, $7\frac{1}{2}$, $11\frac{1}{4}$ and 15 g P_2O_5. This phosphate was added to the soil in two different ways: (*i*) dissolved in water and mixed with the whole of the 32 lb. air-dry soil, and (*ii*) powdered and applied at the bottom of the furrow in a strip two by five inches and covered with one inch of soil before placing the seed piece on top of it. The 5×2 treatment combinations were duplicated in two randomized blocks. All treatments received a basic dressing of 40 g precipitated chalk, which was intimately mixed with the dry soil before moistening with the phosphate solution took place, and a fertilizer solution containing $12\frac{1}{2}$ g ammonium sulphate, $12\frac{1}{2}$ g muriate of potash and 3 g magnesium sulphate. Two-eye seed pieces of the variety B 37–172 were pre-germinated in sand and transplanted, after selection, 10 days later. During the period of growth a constant water level was

maintained in the reservoir at the bottom of the containers and length measurements were carried out at two-week intervals. Finally the plants were reaped, the fresh weights taken and the oven-dried, pulverized aerial parts analysed for total phosphate.

Experimental Results and Conclusions

(*i*) *Growth Measurements:* In *Figure 1*, the average total shoot length per



	Age of cane in weeks						
	2	4	6	8	10	12	
P0	22	31	118	197	367	432	metres
P1	20	35	158	242	497	582	,,
P2	21	35	177	285	540	657	,,
P3	23	36	221	346	637	741	,,
P4	22	37	203	333	606	730	,,

Figure 1. Preliminary test—total length of shoots measured at two week intervals for the five phosphate treatments

container, at intervals of two weeks growth, is presented for the five phosphate dressings. The graph reveals clearly that during the first four weeks the plant lives mainly on the phosphate reserves available in the seed pieces

($\pm$ 25 mg P_2O_5), whereas at tillering time the total shoot length definitely increases with larger phosphate dressings. Only the highest dressing of 15 g P_2O_5 exerts a slight depressing effect.

(*ii*) *Yield Figures:* The statistical analysis of the fresh weight figures, presented in *Table 1* proves a highly significant response (P = 0·01) to phosphate treatments and to methods of placement, and interaction between phosphate effect and placements is also highly significant. These data, graphically presented in *Figure 2*, indicate that with concentrated placement

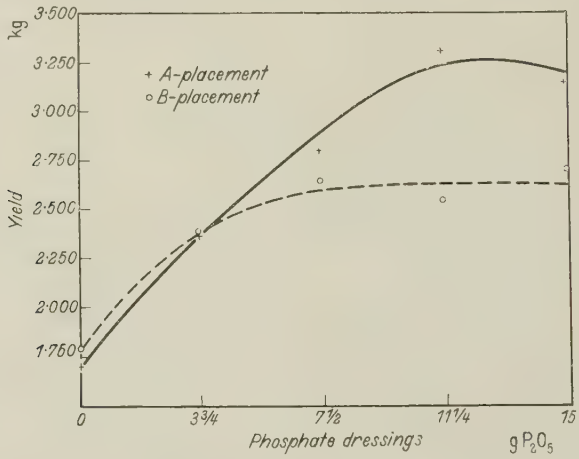


Figure 2. Representation of yield figures from Table 1

of the phosphate beneath the seed piece no further yield responses can be obtained with phosphate applications higher than approximately 5 g P_2O_5. When the phosphate was dispersed throughout the rooting volume and the contact area between phosphated soil and absorbing root surface thus greatly enlarged, yields increased with phosphate dosages up to $11\frac{1}{4}$ g P_2O_5. It also follows that with any method of placement a steep response curve and accordingly greatest sensitivity to changes in the effectiveness of various phosphate dressings may be expected between dressings up to $7\frac{1}{2}$ g P_2O_5.

Table 1. Yield Figures (Preliminary test)

Fresh weights in kilograms							*Analysis of variance*			
Placements of phosphate	*Levels of phosphate dressings*						*Treatment*	D.F.	M.S.	F.
	P0	P1	P2	P3	P4	*Totals*				
A. *Dispersed*	1·66	2·38	2·81	3·29	3·15	13·29	*Totals*	19	6411	
							Blocks	1	32	
B. *Concentrated*	1·82	2·42	2·67	2·61	2·73	12·25	P-*levels*	4	25668	118++
Totals	3·48	4·80	5·48	5·90	5·88	25·54	*Placements*	1	5408	24·9++
Index (per cent)	100	138	157	170	169		*Phosphate × placements*	4	2933	13·9++
							Error	9	217·6	

(*iii*) *Total Uptake of Phosphate:* The total weight of P_2O_5 taken up by the aerial parts of the plants was 290 mg P_2O_5 in the no-phosphate treatments. With dressings of $3\frac{3}{4}$, $7\frac{1}{2}$, $11\frac{1}{4}$ and 15 g P_2O_5 however, these total uptake figures were 529, 720, 915 and 1060 mg P_2O_5 respectively with dispersed phosphate supply and 584, 695, 733 and 823 mg P_2O_5 respectively with concentrated phosphate placement. This also seems to confirm that concentrated phosphate placement was less efficient.

THE FINAL POT TEST

Experimental Procedure

In this final test the four ways of applying phosphate listed below were compared at three phosphate levels, in the absence and presence of lime.

The four forms in which phosphate was applied were:

F1 mono-calcium phosphate, $CaH_4(PO_4)_2 \cdot 1$ aq, dissolved in water and mixed through the whole volume of soil, exactly as was done in the initial trial.

F2 mono-calcium phosphate, $CaH_4(PO_4)_2 \cdot 1$ aq, in powdered form, spread equally through the top 6 in. of soil.

F3 di-calcium phosphate, $Ca_2H_2(PO_4)_2 \cdot 4$ aq, in powdered form, spread equally through the top 6 in. of soil.

F4 tri-calcium phosphate, $Ca_3(PO_4)_2$, in powdered form, spread equally through the top 6 in. of soil.

In order to avoid side effects from impurities, all phosphate sources used were pure chemicals.

The three levels at which the phosphate was applied were chosen at 0, $2\frac{1}{2}$ and 5 g P_2O_5, on account of the findings in the preliminary trial. These dressings are equivalent to applications of 0, 1 and 2 cwt. of superphosphate (20 per cent) to an acre of 4,000 plants. Portions of 4·438 g mono-calcium, 6·062 g di-calcium, and 5·463 g tri-calcium phosphate were weighed off for the dosage of $2\frac{1}{2}$ g P_2O_5 and the double weights were taken for the dosages of 5 g P_2O_5. The powdered phosphates were mixed with dry powdered soil as a diluent and then mixed into the top 6 in. of soil in the containers.

The lime dressing used was 10 g of precipitated chalk per kilogram of air-dried soil. This dressing is later on called : L1, and the unlimed series is called: L0. The $4 \times 3 \times 2$ treatment combinations were duplicated in two randomized blocks of 12 double kerosene tins each. The double tins were used as a split plot, the limed and unlimed phase of each F $\times$ P treatment being allocated to each half. (*See* Paper I, p. 6.) An overall dressing of 25 g ammonium sulphate, 25 g muriate of potash and 1 g magnesium sulphate was added to each tin. Contrary to the practice adopted in the preliminary test, single-eye seed pieces of the same variety B 37–172 were used in this final test. After being pre-germinated in sand and selected in the usual way, the seed pieces were planted in a very shallow furrow of only 2 in. depth, so as to enable the young root system to explore the whole of the phosphate top layer right from its earliest development. The plants were reaped after a growth period of 14 weeks. In *Table 2* the yield figures for tiller count and

total shoot length are given. In *Table 3* the yield figures for fresh weight of the aerial parts are presented together with a statistical analysis of these data. After having taken the fresh weights, the yields from each container were dried, pulverized, weighed again and total phosphate and nitrogen content of this material was determined. In *Table 4* the weight of phosphate taken up by the aerial part of each plant is presented, whereas the total nitrogen percentage of the oven-dried plant material is listed in *Table 5*.

Table 2. Yield Figures (Final test)

	Number of tillers						*Total shoot length in metres*					
	F1	F2	F3	F4	*Total*	*Index (per cent)*	F1	F2	F3	F4	*Total*	*Index (per cent)*
P0	53	67	64	64	248	100	13·08	15·40	14·75	15·96	59·19	100
P1	59	81	67	52	257	104	17·77	21·44	17·12	14·43	70·76	120
P2	71	85	73	78	307	124	19·35	23·67	19·65	19·10	81·77	138
L0	109	142	128	133	512	100	31·73	36·34	33·59	34·12	135·78	100
L1	74	91	76	61	302	59	18·47	24·17	17·93	15·37	75·94	56
Total	183	233	204	194	814	(*Grand total*)	50·20	60·51	51·52	49·49	211·72	(*Grand total*)
Index (per cent)	79	100	88	83			83	100	85	82		

Table 3. Yield Figures (Final test)

	Fresh weights in kilograms						*Analysis of variance*			
	F1	F2	F3	F4	*Total*	*Index (per cent)*	*Treatments*	D.F.	M.S.	F.
P0	2·04	2·06	2·14	2·30	8·54	100	*Totals*	46		
P1	2·77	3·42	2·80	2·33	11·32	133	*Main plots*	23	524	2·59
P2	3·07	3·89	3·20	2·68	12·84	150	*Blocks*	1	363	1·80
							F(*forms*)	3	629	3·11+
L0	5·27	5·85	5·41	5·30	21·83	100	P(*phosphate*)	2	2971	14·70++
L1	2·61	3·52	2·73	2·01	10·87	50	F × P	6	272	1·35
							Error (i)	11	202	
Total	7·88	9·37	8·14	7·31	32·70	(*Grand total*)	*Split plots*	24		
							L(*lime*)	1	25025	139·03++
Index (per cent)	84	100	87	78			L × F	3	134	0·74
							L × P	2	521	2·89
							L × F × P	6	180	
							Error (ii)	12		

Sign. difference for P=0·05 P=0·01
F-*totals* 1·44 1·95
P-*totals* 1·76 2·39

Precision of experiment:

$$\frac{202 + 180}{2} \times \frac{4800}{3270} = 20 \textit{ per cent}$$

Conclusions from Experimental Data

(*i*) *Tiller counts and shoot length :* From the index percentages in *Table 2* it follows that there is a definite response to both phosphate dressings P1

and P2. Only the P2 dressing increases the tiller count by 20 per cent, whereas each of the two dressings, P1 and P2, increases the total length of shoots by 20 per cent. The sensitiveness of the comparison between forms of fertilizers is assured by the magnitude of these responses to phosphate levels P1 and P2.

Table 4. Phosphate Uptake (Final test)

Milligrams P_2O_5 taken up by aerial part of cane

	F1	F2	F3	F4	*Total*	*Index (per cent)*	*Weight index (per cent)*
P0	821	986	1018	1112	3937	100	100
P1	1538	1874	1478	1289	6179	157	133
P2	1526	2072	1879	1709	7186	183	150
L0	2360	2919	2933	2988	11200	100	100
L1	1525	2013	1442	1122	6102	54½	50
Total	3885	4932	4375	4110	17302 (*Grand total*)		
Index (per cent)	79	100	89	83	*Average uptake per plant:* 360 mg P_2O_5		
Weight index (per cent)	84	100	87	78			

Table 5. Nitrogen Uptake (Final test)

Percentages Nitrogen in oven-dried aerial parts

	No Lime	*Lime*	*Total*	*Mean (per cent)*
P1 *dressing*				
F1	1·36	1·13	2·49	
F2	1·39	1·14	2·53	
F3	1·45	1·16	2·59	
F4	1·46	1·05	2·51	
Total	5·46	4·48	10·12	*1·26*
P2 *dressing*				
F1	1·61	1·30	2·91	
F2	1·46	1·27	2·73	
F3	1·68	1·25	2·93	
F4	1·57	1·33	2·90	
Total	6·32	5·15	11·47	*1·43*
Grand total	11·96	9·63	21·59	
Mean (per cent)	1·50	1·20		

Analysis of variance

	D.F.	M.S.	F.
Totals	15		
Replicates (F 1,2,3,4)	3	28·3	
P(*phosphate*) (P 1,2)	1	1139	30·7++
L(*lime*)	1	3393	91·5++
P × L	1	0	
Error	9	37·1	

Comparing the effect of the four forms of applying phosphate and taking F2 as a standard with an index percentage of 100 (F2=mono-calcium phosphate in powdered form spread through top 6 in.), the relative effectiveness of the di-calcium and tri-calcium phosphate (=F3 and F4 respectively) follows directly from the index figures, which are 88 per cent and 83 per cent for tiller counts, and 85 per cent and 82 per cent respectively for shoot length. It also appears that the F1 form, of mixing the mono-calcium

phosphate in solution with the whole of the soil volume is inferior to the standard method (F2) under these experimental conditions. Finally it should be noted that the heavy lime application (L1) depressed the yield by more than 40 per cent. The probable reason for this unusual effect will be discussed later.

(*ii*) *Fresh weights*, as presented in *Table 3*, show the same trend as shoot lengths: fixing the F2 treatment again at an index of 100 per cent, gives 87 per cent for F3, 78 per cent for F4 and 84 per cent for F1. The statistical analysis of these results shows that the response to forms of fertilizers is significant, but that only F2 is highly significantly better than all the others and that the effect of F1, F3 and F4 is about the same, although F4 tends to have the least of all forms of fertilizers. The yield depression caused by lime is very pronounced, being 50 per cent. No significant interaction is found between lime and phosphate, the response to phosphate being the same in the L0 and in the L1 series.

(*iii*) *Figures for total phosphate uptake* by the plants (*Table 4*) denote that with phosphate dressing P1 (=$2\frac{1}{2}$ g P_2O_5) and P2 (=5 g P_2O_5) the total P_2O_5 uptake not only increased as a result of increased total weight of the plant, but also by a higher level of phosphate in the plant tissues. The variations in P_2O_5 uptake for forms of fertilizers (F1 to F4), however, are mainly due to corresponding variations in total plant weights. It is interesting to note that with F2 (=mono-calcium phosphate placed in top 6 in.) a better yield and a higher P_2O_5 concentration in the plant was obtained with only $2\frac{1}{2}$ g P_2O_5 dressing, than with any of the other forms (F1, F3 and F4) when applied at the double dosage of 5 g P_2O_5. The economic use of phosphatic fertilizers is closely connected with the proper choice of fertilizer type and placement.

Comparing the index figures for the L0 and L1 treatments, it follows that the depressive effect of lime on the total P_2O_5 uptake is caused exclusively by the depression of the fresh weight figures and even that a slightly higher phosphate concentration is found in the plant tissues of the L1 series.

(*iv*) *The nitrogen uptake* of the plants provides an explanation for the curious yield depression caused by the lime treatment. *Table 5* shows that the average nitrogen percentage in the oven-dried material from the L0 series is 1·50 per cent compared with 1·20 per cent in the L1 series. This difference is highly significant. The importance of this difference is the more obvious as suppressed growth in the L1 series, caused by any factor other than the nitrogen supply, would have increased the concentration of nitrogen in the plant tissues rather than diminished it. On the strength of the above considerations, and by analogy with experimental results presented in Paper IV of this series, it is suggested that during the very hot and dry period in which this experiment was carried out, the limed series suffered considerable nitrogen losses through volatilization, brought about by the interaction between added ammonium sulphate and free calcium carbonate in the L1 series. The nitrogen percentage of 1·20 per cent in the plant material of the limed series must certainly be considered as inadequate, whereas the percentage of 1·50 in the unlimed series is about sufficient to maintain healthy growth.

GENERAL DISCUSSION

The following facts have been established by this investigation:

(1) Concentrated placement of mono-calcium phosphate immediately beneath the seed piece proved to be less efficient at higher phosphate levels than the dispersal of the same amount of mono-calcium phosphate throughout the whole rooting volume. At lower levels of phosphate application, however, dispersal is not superior to concentrated placement, as in these circumstances the concentration of phosphate in the soil becomes too low.

(2) If dispersed application is compared with the placement of the same amount of phosphate in powdered form mixed with the top 6 in. of soil at relatively low levels of $2\frac{1}{2}$ and 5 g P_2O_5 dosages, it is shown to be definitely inferior.

(3) From these data it appears that apparently two factors are involved when the efficiency of phosphate dressings and phosphate placements are tested.

(*a*) When the contact area between phosphated soil and active root-hair surface is reduced too much, as in the case of concentrated placement beneath the seed piece, the efficiency of the dressing is also greatly reduced.

(*b*) When the concentration of the phosphate in the soil is too low, the uptake of phosphate is also reduced although most of the active root-hair surface is in contact with the phosphated soil. This is the case if the volumes of soil treated with small quantities of phosphate are too large. Under these circumstances the chemical phosphate-binding properties of the soil are accentuated to the disadvantage of the phosphate-absorbing properties of the roots, shifting chemical fixation in the direction of physiological phosphate fixation.

The importance of the fact that different combinations of the two factors involved may lead to apparently contradictory results has been clearly stressed and demonstrated by GOEDEWAAGEN (1942). It is of the utmost importance that the two factors are combined correctly and that the two extremes, too much dilution of small phosphate dosages with large soil volumes and too concentrated placement when dealing with big root systems, should be avoided in order to ensure the most efficient utilization of a given phosphate dressing under field conditions.

(4) Mono-calcium phosphate when compared with di-calcium and tri-calcium phosphate, when used as powdered phosphate mixed dry throughout the top 6 in. layer of soil, proved to be more efficient, both in the acid unlimed soil as well as in the limed soil. Under the artificial conditions of the experiment which ensured an ideal mixing of the powdered phosphates with the soil, the effectiveness of di-calcium and tri-calcium phosphate did not differ significantly, although the tri-calcium phosphate tended to be the less effective phosphate carrier.

SUMMARY

(1) A Type 3 pot test (Paper 1) in which sugar cane was grown in 4 gal. kerosene tins for 14 weeks, is described. The soil was highly acid and low in phosphate and was derived from the same batch of soil as was used in the experiment described in Paper IV of this series.

(2) In a preliminary and a final test the efficiency of three different placements of mono-calcium phosphate were compared and also the relative efficiencies of mono-calcium, di-calcium and tri-calcium phosphate were tested in the presence and absence of lime when spread through the top 6 in. layer of soil.

(3) Final yield data, *i.e.* tiller count, total shoot length and fresh weights of aerial parts, were taken as indicators for treatment responses and the results were statistically analysed. The precision of the experiment was satisfactory, as the coefficient of variation of the error was 20 per cent of the mean yield.

(4) The data obtained demonstrated that the response to any phosphate dressing depends on two factors, *i.e.* the contact surface area between roots and phosphated soil and also on the ' dilution ' of the phosphate dosage with volume of soil. Efficient phosphate placement technique should be based on the proper balance between these two factors. This balance again depends on the characteristics of any specific root system.

(5) Under conditions of the experiment, mono-calcium phosphate was the more efficient phosphate carrier under both unlimed and limed conditions ; di-calcium, and tri-calcium phosphate being equally but less effective.

(6) Lime treatment caused considerable yield depression, which was proved not to be related to diminished phosphate availability, but was most likely caused by considerable losses of nitrogen through volatilization in the limed series. These losses may also be anticipated in the field, if ammonium sulphate dressings are applied on top of marly or calcareous soils and left uncovered during hot and dry weather.

(*Received May 1954*)

REFERENCES

GOEDEWAAGEN, M. A. J. (1942). ' Het wortelstelsel der landbouwgewassen ', pp. 142–155 *Bull. Rykslandb. Proefst. Bodemk. Inst., Groningen*

SCHROO, H. (1953). *Trop. Agriculture, Trin.*, **30,** Nos. 10–12 Paper I, 199–205; (1954) *ibid.*, **31,** No. 1, Paper III, 71–78; (1954) *ibid.*, **31,** No. 2, Paper IV, 161–172

The Use of Foliar Analysis in Oil Palm Cultivation

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INTRODUCTION

During recent years, the limitations in the use of soil analytical data as a reliable diagnostic tool on which to base advice on fertilizer policy for any given area, have become more apparent, particularly under tropical conditions. The situation is somewhat different in temperate regions, particularly in Western Europe, where, on the basis of a very wide accumulation of soil data and corresponding responses to fertilizer applications, it is now possible to give practical advice on the most suitable policy to be adopted to obtain optimum production. This desirable state of affairs is still far from being attained in tropical regions, where the problem of appropriate fertilizer applications to perennial, as well as annual, crops is becoming increasingly important. In point of fact, little is known of tropical soils, or of their response to fertilizers, and to date the number and range of appropriate experiments has been too small to enable the necessary information to be accumulated. In addition, knowledge on the behaviour of fertilizers, *e.g.* phosphate, is so limited and unsatisfactory that it will inevitably be many years before soil analysis, as such, may be of use as a reliable basis for advice on fertilizer policy.

In these circumstances, it is not surprising that many investigators have turned their attention to devising other means for determining crop requirements and the nutrient status of the soil with which they have to deal. The classical work on cereals by Lundegårdh (1945) in Sweden, and the complete review of the literature up to 1947 by Goodall and Gregory (1947) gave a valuable lead as to the direction in which these new methods should be sought, namely, by a direct appeal to the crop or the culture by the determination of the chemical composition of the leaves. In recent years, Ollaginier and Prevot (1951), working on groundnuts in the French West African Colonies, and Chapman and Gray (1949), working with oil palms in Malaya, have indicated the value of Foliar Analysis as a diagnostic tool for the determination of the fertilizer requirements of these crops. The former have now reached the stage where advice on fertilizer policy is based directly on the leaf composition ; the latter based their recommendations mainly on the potash/phosphate ratio in the leaves, and were little concerned with the other elements. Working under different conditions, and using modified methods, their findings have not been confirmed by us under Congo conditions. It may fairly be stated, however, that the methods are sufficiently promising to be followed up and the results of recent investigations in the Belgian Congo, as contained in the following paper, tend to

show that the time may not be far distant when Foliar Analysis will be a generally accepted and valuable diagnostic tool.

METHOD

Sampling

It is an essential feature of the method that only leaves of the same physiological age must be compared, irrespective of whether these are taken from single palms, bulk samples taken from experimental plots, or from plantation fields. In the work described below, samples have been taken from the first and the ninth leaves, these having been shown to be the most consistent in composition. Except where otherwise stated, the results refer to the composition of the first leaf, *i.e.* the youngest fully opened leaf.

Samples are taken from the middle part of leaflets from the middle of the frond ; the mid-rib is rejected before the samples are analysed.

Leaf Composition

(*a*) Variations in leaf composition follow the usual pattern ; Ca, and to a lesser extent Mg, content increases with the age of the leaves, while the K and P contents decrease with increasing age of the leaves.

(*b*) In the same leaf, taken from tip to base, the Ca and Mg contents decrease, while the K and P contents increase.

(*c*) Differences in the age of palms have no significant effect on the composition of the first leaf.

(*d*) Seasonal influences on leaf composition may be significant and important, but, for the purpose of this paper, all samples have been taken during the wet season, and are, therefore, directly comparable.

Analytical Methods

The leaflets were cleaned with a cloth before the actual samples were taken ; these were ashed in a muffle furnace at about 450° C. A weighed quantity of ash was digested in a mixture of concentrated sulphuric and nitric acids and made up to 100 ml with distilled water. Silica was filtered off, and, from the extract thus obtained, aliquots were taken for the determination of the K, P, Ca and Mg contents. The results are expressed as a percentage of the ash contents of the samples.

The expression of the analytical data as a percentage of the ash has definite advantages ; investigations in this laboratory have shown that considerable variations in the percentage of ash to dry matter may arise, unless the ashing is carried out, following a standard procedure.

The total analytical error, comprising both the ashing and the chemical determinations, did not at any time exceed 10 per cent.

Potassium Determination—K is precipitated with silver sodium cobaltinitrite. The intensity of the stable blue colour, which develops when ammonium thiocyanate is added to this precipitate, is measured with a Hilger Spekker absorptiometer. The actual percentage of K is read off a graph prepared from the readings obtained from a range of known standard K concentrations.

Phosphorus Determination—The intensity of the blue colour, which develops when ammonium phospho-molybdate is reduced by stannous chloride, is

measured with the Hilger Spekker and the P content read off a graph prepared for P as in the case of the K determination above.

Magnesium Determination—Titan yellow is added to an aliquot of the extract. Caustic soda forms a red lake with the magnesium titan yellow complex ; the intensity of this red colour, as measured with the Hilger Spekker, is a measure of the Mg concentration.

Calcium Determination—The Ca content is determined by the precipitation of the Ca as calcium oxalate and titration with potassium permanganate in the presence of sulphuric acid.

FOLIAR ANALYSIS OF SOME FIELD EXPERIMENTS

Examples of foliar analysis of samples taken from field experiments, which have shown significant growth or production responses to the treatments, will serve to illustrate the sensitivity of the method.

Fertilizer Trial on Young Non-productive Palms

The experiment comprised complete fertilizer application of N, P, K and dolomite at three levels of K. The treatments may be grouped in three series: (*i*) no potash ; (*ii*) low potash (100 g K_2O) ; (*iii*) high potash (200–300 g K_2O).

Table 1 and *Figure 1* show the growth responses and foliar analysis results.

Table 1. Growth Response and Leaf Analysis of Fertilizer Experiment on Young Palms

Treatment	*Average height (cm)*	% K *in leaf*	% P *in leaf*	% Ca *in leaf*	% Mg *in leaf*	K/Ca *in leaf*	K/P *in leaf*
No K	235	20·7	4·12	11·3	3·83	1·96	5·04
Low K	296	23·4	3·75	10·3	3·60	2·33	6·36
High K	318	24·0	3·24	9·41	3·53	2·60	7·51
Sign. diff.							0·67++
at P = 0·05 ..	18·5	1·8	0·25	1·06	not sign.	0·29	0·97++

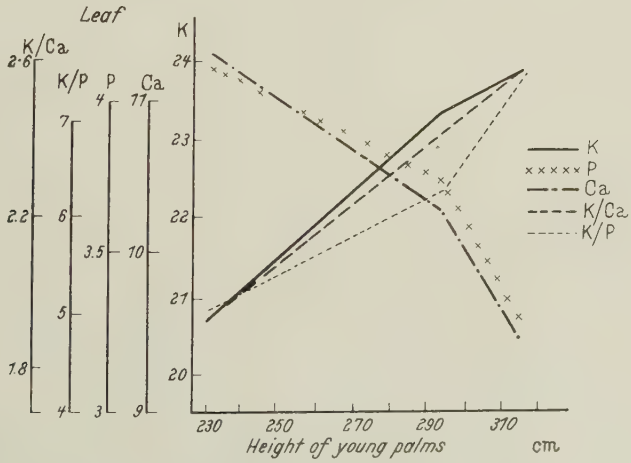

Figure 1. Change in height in cm and leaf composition of young K deficiency palms, after application of potash fertilizer

Significant growth responses to potash applications are accompanied by significant increases in leaf K and significant decreases in leaf Ca and P. The negative correlation between leaf Mg and growth just failed to attain significance. The differences in K/P ratios are significant at the 1 per cent level.

Fertilizer Experiment on Production Palms

In the same area, a fertilizer experiment on productive 14 year old palms was laid down. Two years later, the average production per palm was calculated and leaf samples taken and analysed. The treatments and results are given in *Table 2*.

Table 2. Production and Leaf Analysis: Fertilizer Trial on 14 year old Palms

Treatment	*Production (kg of bunches/ year/palm)*	% K *in leaf*	% P *in leaf*	% Ca *in leaf*	% Mg *in leaf*	K/Ca *in leaf*	K/P *in leaf*
Potash	76·8	26·2	2·22	7·02	3·33	3·73	11·8
N. P. K. Dol. ..	62·2	28·3	2·87	7·00	3·57	4·11	9·84
Treatments without K	30·7	25·4	3·75	10·4	3·42	2·41	6·9
Sign. diff. P = 0·05	15	2·6	0·32	0·85	0·33	0·32	0·90

The effect of potash dressings on production and leaf composition is striking. There is no significant difference in the responses to K and N, P, K dolomite dressings ; both have resulted in a virtual doubling of the production. As in the case with young palms, increased production is accompanied by an increase in leaf K and the K/P and K/Ca ratio. Leaf P and Ca are negatively correlated with production, while leaf Mg did not change as a result of the potash application.

Replanting Experiment with Young Palms

A replanting experiment was laid down to test growth responses under the influence of shade and fertilizer applications. The design was a 4 × 4 Latin square with the following treatments :

(*a*) The old stand of palms was felled before the young palms were planted but no fertilizers were given.

(*b*) The young palms received a complete fertilizer application and were planted under the shade of the old stand of palms.

(*ab*) The old stand was felled and the young palms received fertilizers.

(*i*) Control ; the young palms were planted under shade and did not receive any fertilizers.

Table 3 shows the growth responses and change in leaf composition resulting from the different treatments. The young palms were three years old when the samples were taken and growth measurements made.

Table 3. Growth Response and Leaf Analysis Results Replanting Experiment

Treatments	% K *in leaf*	% P *in leaf*	% Ca *in leaf*	% Mg *in leaf*	*Increase in number of leaves*
Felling (a)	28·4	4·35	9·05	3·5	8·22
Fertilizing (b)	24·7	4·07	8·02	4·95	6·60
Felling + Fertilizing (ab) ..	28·6	3·2	6·45	3·8	11·11
Control (i)	13·4	6·8	13·9	4·2	4·26
Sign. diff. at P = 0·05	4·4	0·7	1·9	0·4	0·38
Main effects:					
A. *Felling*	9·4++	−1·6++	− 3·2	−0·8++	4·24++
B. *Fertilizing*	5·7++	−1·9++	− 4·3	0·5 +	2·62++
Sign. main eff. P = 0·05	3·1	0·5	1·5	0·3	0·27
Interaction A × B..	−11·3++	1·5+	3·3+	−0·45	0·55
Sign. interac. at P = 0·05 ..	6·3	1·0	2·7	0·6	0·54
General mean	23·7	4·6	9·4	4·1	
Error	2·4	0·4	1·1	0·23	
Error/per cent mean	10	8·7	11	5·6	

+ = sign. at P = 0·05 ++ = sign. at P = 0·01

Concurrently with the significant growth responses, as measured by the number of new leaves produced, leaf composition resulting from the various treatments has changed significantly. The combination of felling and fertilizing caused an increased production of leaves, together with an increase in leaf K and a decrease in leaf Ca and leaf P. The plots which received only fertilizers showed a significantly higher leaf Mg, while felling had the opposite effect, a reduction in leaf Mg.

Further, when growth per plot was compared with leaf composition, there was a positive correlation between leaf K and the K/P and K/Ca ratios, but a negative correlation between leaf P and Ca and growth ; this is illustrated in the graphs (*Figure 2*).

FERTILITY GRADIENT IN A PLANTATION

In order to determine how far existing differences in production between blocks, where potash had given positive growth and production responses in fertilizer experiments, could be ascribed to a quantitative difference in the potassium status of the palms, a series of blocks of known production were sampled and analysed. They are situated in a line perpendicular to the course of a large river. The table overleaf gives the block number, average production in tons of bunches per hectare per year over a period of four years, and the results of foliar analysis. In this case the ninth leaf was taken for the purpose of the analysis. (The ninth leaf has its leaf base immediately below the first leaf.)

With the aid of dot diagrams it will be apparent that the production of the several blocks is positively correlated with leaf K and with the K/P and the K/Ca ratios, but negatively correlated with leaf Ca and P. This is clearly shown in the graphs.

Following this procedure, maps of existing plantations may be prepared showing those areas which are deficient in a certain element and the magnitude of the deficiency.

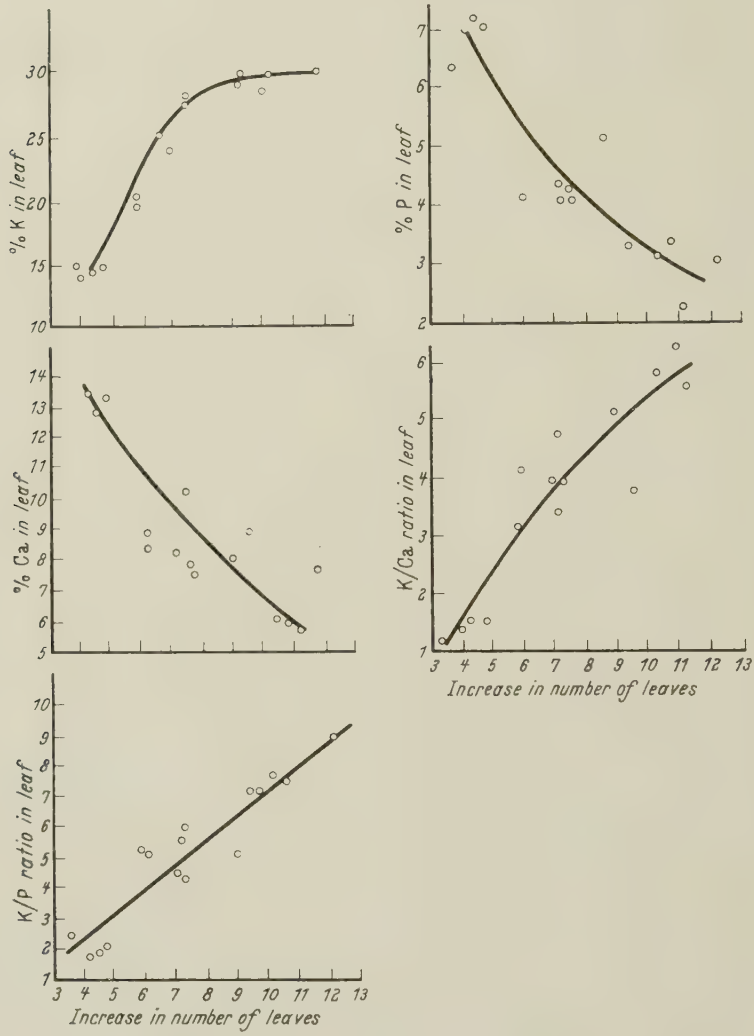

Figure 2. Correlation between the increase in number of leaves and leaf composition of young palms of replanting experiment

Table 4. Production and Leaf Analysis of a Series of Blocks in a Plantation with Potash Deficiency

Block	*Average production (tons of bunches/ha./year)*	% K *in leaf ash*	% P	% Ca	Mg	K/Ca	K/P
26	5·5	19·5	1·88	10·6	4·72	1·84	10·4
27	6·5	21·2	1·90	10·2	4·50	2·07	11·1
28	5·7	16·7	1·75	9·86	3·01	1·69	9·5
29	4·7	16·0	2·05	11·2	3·58	1·43	7·8
30	4·0	14·0	1·90	11·3	3·40	1·24	7·4
31	3·7	16·3	2·15	11·1	4·06	1·47	7·9
32	4·1	15·2	1·94	10·2	3·45	1·9	7·8
83	3·2	14·8	2·15	11·0	3·84	1·34	6·9
98	3·9	14·5	2·18	11·6	4·11	1·25	6·6

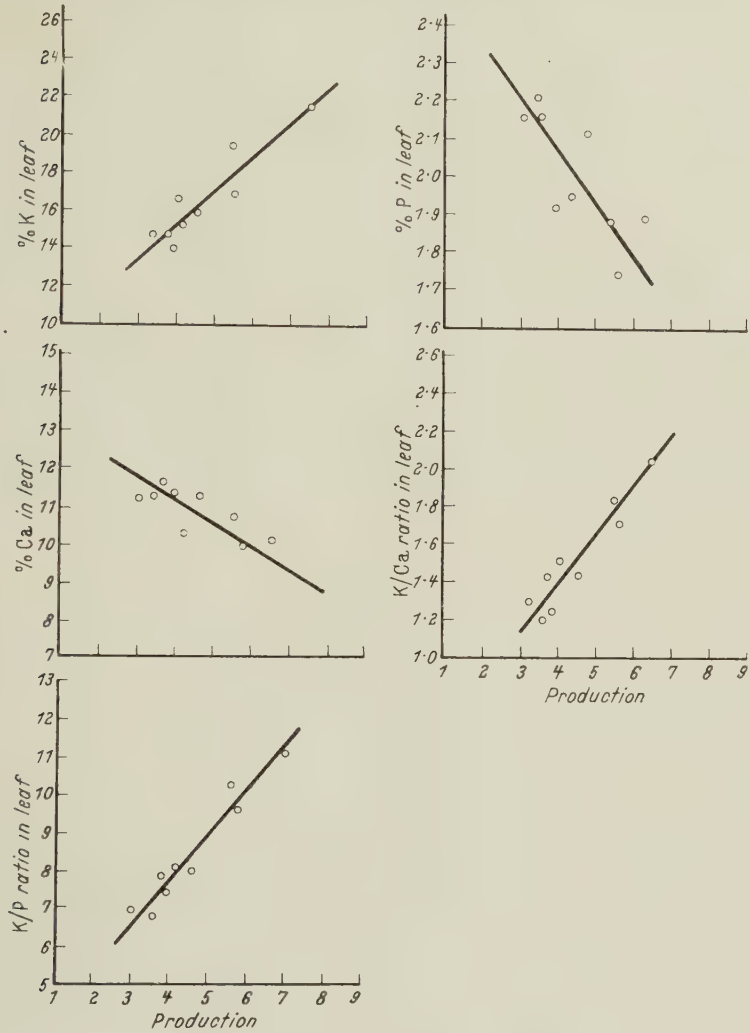

Figure 3. Correlation between the production in tons of bunches/hectare/year (4 year period) and leaf composition in potash deficiency area

As regards the quantities of fertilizer to be applied, the figures, as such, do not give any direct information. Experiments with fertilizers at varying levels of application will show the changes in leaf composition for a particular increase in production : once this is known, the necessary indications may be given in respect of the quantity of fertilizer to be applied dependent upon the magnitude of the deficiency.

PHOSPHATE DEFICIENCY

The preceding section dealt with the case of potash deficiency, as it obtains in some parts of the Southern Congo. An indication of phosphate deficiency has been found in the north of the Central Congo basin.

The area of lowest production in the plantation showed the lowest leaf P and Ca, whereas K was very high.

The leaf composition varied between the following values :

K 27–28 per cent, P 2·2–2·7 per cent, Ca 4·6–5·2 per cent, Mg 3·3–4·2 per cent.

The palms in this area showed a response to a phosphate application.

DISCUSSION

In the foregoing it has been shown that potash applications to palms of varying ages have resulted in positive responses in growth and production, while leaf composition has shown increases in leaf K and in the K/P and K/Ca ratios, with decreases in leaf P and Ca.

On the basis of the accumulated data, triangular diagrams have been prepared for the elements K, Ca and Mg, and for K, P and Ca, showing the relations of the leaf contents of the individual elements, expressed as a percentage of the sum of the elements concerned. From these diagrams, it has been possible to indicate the optimum leaf composition and relationship between the several elements. For K, Ca and Mg, this has been shown to be as follows :

K	67–70 per cent
Ca	19–24 per cent
Mg	10–13 per cent

The figures are expressed as a percentage of the sum of the actual quantity of elements in the leaves, as determined by analysis.

Based on the ash content, these figures would become :

K	25–26 per cent of leaf ash
Ca	7–9 per cent of leaf ash
Mg	3·7–4·8 per cent of leaf ash

On the same basis, leaf P would vary between 2·5 and 2·9 per cent of leaf ash.

From the diagrams it will be seen that growth and production responses, induced by fertilizer applications on soils deficient in K, result in changes in leaf composition, which are always directed towards the optimum point in the diagrams. Points below this optimum content indicate areas of potash deficiency, and points above, indicate those with phosphate deficiency. The antagonism between K and Ca is clearly demonstrated in *Figure 4*, and further, that when K is very deficient, there is a tendency towards an antagonism between K and Mg.

CONCLUSIONS

The chemical composition of leaf ash of oil palms may be used as a reliable guide in respect of the nutrient status of plantations.

Resulting from the analysis of a large number of samples taken from field experiments and plantation areas, it has been concluded that there is an optimum composition of the leaf ash for the elements K, P, Ca and Mg. Both the actual percentages and the ratios between the elements give valuable indications as regards the type and degree of deficiency, and from these data appropriate fertilizer applications may be recommended as general policy.

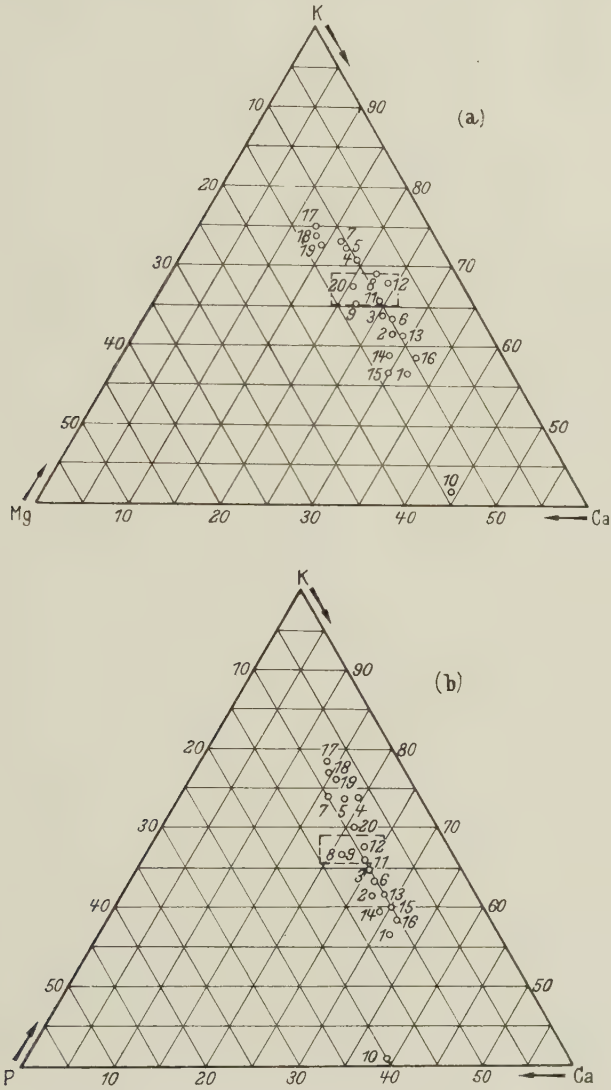

Figure 4. Triangular diagrams giving the relationship between growth/production of palms and leaf composition

On the data at present available, it is not yet possible to recommend optimum applications, and this will only become possible when further data from field experimentation have been accumulated.

ACKNOWLEDGMENTS

The writer wishes to express his indebtedness to Huilever S.A. for permission to publish this paper. He further wishes to express his acknowledgment to Mr. E. A. Evans, Head of the Soil Section, who inaugurated this

Table 5. Relationships Between K, Ca, Mg, P *and Production or Growth of Oil Palms*

No.	*Description*	*Total* K + Ca + Mg	K (% *of total*)	Ca (% *of total*)	Mg (% *of total*)	*Total* K + Ca + P	K (% *of total*)	Ca (% *of total*)	P (% *of total*)
1	*Young palms no* K (*Table 1*)	35·8	57	31	12	36·1	57	31	12
2	*Young palms low* K (*Table 1*)	37·3	62	27	11	37·5	62	27	11
3	*Young palms high* K (*Table 1*)	36·9	64	25	11	36·7	65	25	10
4	*Old palms* K (*Table 2*)	36·6	71	19	10	35·4	74	19	7
5	*Old palms* N, P, K, Dol. (*Table 2*)	38·9	72	17	11	38·2	74	18	8
6	*Old palms no* K (*Table 2*)	39·2	64	26	10	39·6	64	26	10
7	*Young palms (ab)* (*Table 3*)	38·8	73	16	11	38·3	74	16	10
8	*Young palms (a)* (*Table 3*)	40·9	69	22	9	41·8	67	21	12
9	*Young palms (b)* (*Table 3*)	37·6	65	21	14	36·8	67	21	12
10	*Young palms (i)* (*Table 3*)	31·5	42	44	14	34·1	39	40	21
11	*Plantation blocks with good production in area with* K *deficiency*	37·21	66	24	10	37·2	66	24	10
12	,, ,, ,,	34·5	68	24	8	34·7	68	23	9
13	*Plantation blocks with low production in area with* K *deficiency*	37·0	62	28	10	37·4	62	28	10
14	,, ,, ,,	37·3	59	28	13	36·5	60	29	11
15	,, ,, ,,	32·7	57	29	14	31·3	60	30	10
16	,, ,, ,,	35·9	59	31	10	35·9	59	31	10
17	*Plantation blocks in area with* P *deficiency*	38·0	75	12	13	36·5	79	13	8
18	,, ,, ,,	38·4	74	13	13	36·4	78	14	8
19	,, ,, ,,	37·4	73	14	13	35·7	77	15	8
20	*Young palms on recently felled forest area*	37·9	67	20	13	35·9	71	21	8

work ; to Mr. J. D. Ferwerda, Agronomist, for permission to use the data from his experiments ; and to Mr. S. de Blank for encouragement and help in the preparation of this paper.

(*Received February 1954*)

REFERENCES

LUNDEGÅRDH, H. (1945). ' Die Blattanalyse '. G. Fischer, Jena

GOODALL, D. W. and GREGORY, F. G. (1947). ' Chemical composition of plants as an index of their nutritional status.' *Tech. Commun. No.* 17. *Bur. Hort., E. Malling*

PREVOT, P. and OLLAGINIER, M. (1951). ' Application du diagnostic foliaire a l'arachide.' *Oléagineux*, June

CHAPMAN, G. W. and GRAY, H. M. (1949). ' Leaf analysis and the nutrition of the oil palm.' *Ann. Bot., N.S.* **13,** No. 52

Book Reviews

VEGETABLE TANNING MATERIALS

F. N. Howes, D.Sc. Royal Botanic Gardens, Kew. Butterworths Scientific Publications, 1953. 325 *pp.* 35*s*

Into a relatively small compass the author has managed to compress a mass of information, with the result that, with the exception of the introduction, this is a book for reference rather than for reading. It is divided into eight sections, the first of which is a very brief introduction dealing with the nature, distribution, uses, *etc* of tannins. In the following seven sections the tannin-producing plants are dealt with under the part of the plant from which the tannin is extracted—barks, woods, fruits, leaves, roots, plant galls and miscellaneous. Of particular interest in the tropics, of course, is mangrove bark, the mangrove being common and virtually unexploited on many muddy seashores and estuaries. As other sources such as quebracho and chestnut wood are used up the tropical mangrove and the sub-tropical wattle seem likely to increase in importance, and tannin-containing plants generally merit study as a source of useful minor industries, particularly in countries with abundant forests.

The book is well printed on good paper and is illustrated with botanical drawings of the plants concerned and also with photographs illustrating the extraction and use of the tannin-containing materials. A book which every department or institute with an interest in minor industries should possess.—R.E.D.B.

MECHANIZATION IN AGRICULTURE IN THE RAINLANDS OF THE ANGLO-EGYPTIAN SUDAN, 1948–1951

R. G. Laing. Ministry of Agriculture, Sudan Government, 1953. 82 *pp.* with maps, mimeographed

Since Clouston (1948) gave us his 'Mechanization in Agriculture in the Rainlands of the Anglo-Egyptian Sudan, 1943–48' much progress has been made. An area of some 350,000 acres of dark calcium clay is involved, over which the rainfall averages about 20 in. per annum, but is very variable. The main crop is sorghum. The most recent report by Laing, carries us forward another three years, to 1951, and contains much very useful information. It is interesting to note that the machinery capitalization of the combined Un Leigun and Um Suqura schemes of 20,000 feddans under crop is rather higher than (*a*) the capital cost of housing plus water supplies plus access roads, and (*b*) bush clearance plus grass eradication plus internal roads, each group costing roughly £3 per acre. The cultivators participate as share-croppers and in 1951 their shares amounted to a return of £E.20·26 on a 28 acre holding. It is concluded that whether or not the schemes pay their way—and the losses will not be great in any case—the social benefits fully justify the establishment of more schemes of the same kind.—J.E.M.

LAND DEVELOPMENT IN SURINAM

Experiences in Growing Crops and Crop Protection in the Prins Bernhard Experimental Polder, Surinam

Report No. 4, Netherlands Advisory Board for the Mechanization of Agriculture in the Overseas Territories, Wageningen/Holland, 1954

Previous reports have contained background information, results of experiments in chemical clearing of forest, and experiences during the empoldering processes. Rice is the main crop. Other annuals might be used in a rotation. Most dry-land annuals have not been successful on the flat, but ridges are not used, so that the land will remain level for the paddy. Dry-crops have been limited to soya beans and forage grasses. One hectare (2·5 acres) supplies eight cows with fodder. Both water-level and chemical methods of weed control are described. High and low volume sprayers, knapsack and tractor-mounted, have been used for pest control.—J.E.M.

PLANT DISEASES, THE YEARBOOK OF AGRICULTURE, 1953

United States Department of Agriculture. U.S. Govt. Printing Office. 940 *pp.*, 32 coloured plates. $2·50

Since 1936 each volume of the yearbook has been devoted to discussions on a single field of knowledge, and this is the first time that Plant Pathology has been chosen. The object of each yearbook is to give a complete, clear and practical discussion of one topic, primarily for the benefit of American farmers, but workers in the tropics will find much to interest them.

Amongst articles of general interest are ' Problems of Variability in Fungi ' by E. C. Stakman and J. J. Christensen, ' The Effect of Weather on Diseases ' by Paul R. Miller, and three papers on Resistance to Disease.

Of more particular interest to pathologists in the tropics is the section on cotton (seven articles) and articles on maize, sorghums, tobacco, sugar, citrus and vegetables. The review of the diseases of sugar cane by E. V. Abbott is particularly valuable, and papers like those of T. J. Grant and others on the Tristeza disease of Citrus are valuable in bringing information up to date on a subject on which little has been published, at any rate in English.

Well printed on good paper, this yearbook, with nearly 1,000 pages of text and 32 coloured plates, is a real bargain for only $2·50 (U.S.).—R.E.D.B.

REPORT OF THE THIRTEENTH INTERNATIONAL HORTICULTURAL CONGRESS, 1952

The Royal Horticultural Society, Vincent Square, London, S.W.1. Staples Ltd., 1953. 1,297 *pp.* (illus.) £2 2*s*

The Thirteenth International Horticultural Congress was held in London in September 1952, and the Report was issued at the end of 1953. It contains all the papers presented to the congress reproduced in full and is well printed on good paper and profusely illustrated.

Of particular interest to taxonomists is the International Code of Nomenclature for Cultivated Plants edited by William T. Stearn, which has been adopted for trial.

In a report of nearly 1,300 pages there are, of course, papers of general interest such as ' The Uptake of Nutrients by Leaves and Branches of Fruit Trees ' by Dr. H. B. Tukey, and the papers on plant diseases. Many papers, however, are inevitably too specialized in the field of temperate horticulture to be of much interest to workers in the tropics.

The section on tropical and sub-tropical horticulture contains interesting general articles, summaries of breeding programmes on rubber in Malaya and coffee in Brazil and accounts of two tropical diseases, blister blight of tea in Ceylon and cacao virus diseases in West Africa. An article by Dr. H. Evans, formerly Senior Plant Physiologist at the Imperial College of Tropical Agriculture, on the propagation of cacao from cuttings will be of value to all countries where cacao is grown. Papers by Dr. Wilson Popenoe and Mr. A. M. W. Greig deal with the cultivation of fruits in the tropics and sub-tropics. These, together with a symposium on citrus, cover a rather meagre contribution from tropical horticulture.—R.E.D.B.

FARM MANAGEMENT

JAMES WYLLIE. E. & F. N. Spon Ltd., London, 1953. 249 *pp.* 25*s*

This is not a book on tropical agriculture. It could, nevertheless, to advantage be made compulsory reading for agricultural officers in the tropics. It contains at least two messages that must be learnt if tropical agriculture is to progress.

The first is that a farm is a farm. It is neither a factory—a mass-production, one crop plantation ; nor is it a peasant holding—an allotment growing a picturesque assortment of crops with the aid of the rain-maker and other magic, but precious little farm management. A farm is a skilful combination of interrelated enterprises welded into one economic whole. Withal a farm is a means of making a living; the more skilful the management the better the living. Profit is not merely an interesting feature of a farm, it is the very object of farming.

The second message is that modern ' improvements ', although in certain circumstances invaluable aids to more productive farming, are not always so and are certainly not objects in themselves. Their novelty always makes them attractive but none has proved of universal application. There are not, and never will be, any touchstones to profitable farming. A particular innovation may be a useful tool under certain conditions, but impractical, ineffective or too costly in others.

These two messages, derived from and illustrated by temperate agriculture though they be, should carry even more weight in the tropics. Excluding the plantation there are few farms. There are few agricultural undertakings where profit is clearly recognized as the object of farming. The hard facts of raising standards of productivity and living are often shrouded by the agricultural officer and peasant alike in sentimental attachments to certain crops, or livestock or certain methods of farming. Furthermore, a salaried officer is tempted to treat an innovation as an object in itself because there are so many innovations to choose from but so few real systems to work on. He is tempted to ride a hobby-horse which by itself cannot carry agriculture forward.

These messages are carried with authority. For 30 years Mr. Wyllie has worked with his farmers and their accounts in South East England ; he probably has known more farms more intimately and for a longer time than any other economist. As a one time colleague the reviewer has often regretted that Mr. Wyllie has not attracted a larger following of agricultural economists ; his whole philosophy of farming is so sound, realistic and stimulating.

It is a happy augury that Mr. Wyllie has produced such a valuable book so soon after his retirement from active professional life. His philosophy can, through the printed word, reach the wider audience it deserves ; this evidence of productive retirement foreshadows other good things for the future.—A.L.J.

THE SOUTH AFRICAN SUGAR YEAR BOOK, 1952–53

The South African Sugar Journal, Durban. 224 *pp.* 10*s*

This year book is rather a special volume as it commemorates the centenary of the establishment of the sugar industry in South Africa, and it contains, in addition to the usual statistical information and reference material, many articles of general interest to field and factory workers in the sugar industry. The book is attractively produced and abounds in photographs and coloured plates ; it has lost, however, in its new format, the handy size of previous volumes of the South African Sugar Year Book.

Amongst the articles of general interest are accounts of the early days of the South African sugar industry, the life of the pioneer, Edmond Morewood, the South African Sugar Association and the Cane Growers Association, and of the Experimental Station at Mount Edgecombe, including an extensive list of varieties of sugar cane growing there. The structure of the sugar industry, the organizations controlling its general policy, details of the individual companies, their history, their directorates, the make-up of their capital together with the tables of statistical information usually met with in such year books are all included in an interesting and readable book.—L. F. W.

* * *

CORRIGENDUM

Vol. 31, No. 1. ' A Note on Artificial Insemination of Cattle in Nigeria.'

P. 69, last paragraph. *For* " The female cross-breds appear to have no hump, or at the most a slight change in contour. The males, on the other hand, appear to have a hump, although one calf born recently did not." *read* " The cross-breds appear to have no hump or at the most a slight change in contour."

OBITUARY

N. V. Rounce, Dip. Agr., A.I.C.T.A.

By the early death of Norman Rounce the Colonial Agricultural Service has lost a devoted officer who had attained considerable distinction in his profession. Born in 1906, he was educated at Dulwich College and Wye, and was a post-graduate student at I.C.T.A. in 1927–8. He was always a keen rugger player, and while in Trinidad captained the College team in a most successful season ; even after going to Africa, he played for the Old Alleynians during leaves in England. Among his other interests were botany, classical music, and ballet.

Rounce was appointed an agricultural officer in Tanganyika in 1928. Thereafter he remained in that territory, except for a secondment to Zanzibar in 1941–2, and in spite of a number of offers of promotion elsewhere. In 1943 he was promoted to senior agricultural officer, and later to assistant director of agriculture. An early study of Sukumaland agriculture, in collaboration with King and Thornton, was followed by his writing ' The Agriculture of the Cultivation Steppe of the Lake, Western, and Central Provinces ' which was published in English and Swahili; he was also the author of numerous papers in the *East African Agricultural Journal.* It was in his relations with the peasantry and their rulers that Rounce had the greatest success. Besides his agricultural work, he was in the van of progress in developing local government; through the Provincial Council and in his private contacts with leading Africans he had become very influential in this field. He contributed greatly to the agricultural development of north-western Tanganyika; and if his own staff felt at times that he drove them hard, they knew that he did not spare himself either.

Rounce returned from Tanganyika to the United Kingdom for medical treatment early in 1953, but in spite of a courageous resistance to his malady, died on 16 December. He leaves a widow and young son, to whom we extend our sympathy.

S. F. Ashby

(Formerly Professor at I.C.T.A.)

We regret to announce the death of Mr. Sydney F. Ashby who was formerly Professor of Mycology and Bacteriology at the Imperial College of Tropical Agriculture, Trinidad. Mr. Ashby received his early scientific education at Edinburgh University, and afterwards worked during the years 1903–6 as Carnegie Fellow at the Rothamsted Experimental Station, Harpenden, England, in the Department of Bacteriology. At the end of this period he obtained a post as Bacteriologist and Fermentation Chemist in the Department of Agriculture, Jamaica, from which he was promoted in 1912 to a newly-created post of Microbiologist in that department. In 1922, Ashby was appointed to succeed Mr. Wm. Nowell as Mycologist in the Imperial Department of Agriculture for the British West Indies with headquarters in Barbados. It was here that the writer was first associated with him before the College was started in October, 1922. Ashby was Professor of Mycology at the College up to 1926 when he returned to England to take up a post

as Mycologist in the Imperial Bureau of Mycology at Kew near London. Later, he became Director of the Bureau, and eventually retired into private life in 1939.

Mr. Ashby's work in the Imperial Department and at the College afterwards mainly concerned the pathology of tropical crops, notably, sugar cane, coconut, banana and limes, on which he was a recognized authority. He was a regular contributor to the now defunct 'Agricultural News' and to the College Journal, 'Tropical Agriculture', as well as to recognized scientific journals. Ashby was a first-rate teacher and able to impart his enthusiasm to his pupils. In disposition he was retiring and somewhat of a recluse, largely because of his deafness, although to those fortunate to enjoy the privilege of his friendship, he was a delightful companion. He was a great reader and scholar and his range of interests was very wide. Incidentally, he was, in his youth, a keen cricketer and later an effective exponent of the more subtle aspects of tennis. His judgement in matters scientific and administrative was sound and constructive. For those reasons he was a useful member of committees, such as the College Academic Board, where he was never reticent in expressing his views boldly and tersely, thus gaining for himself the respect and confidence of his associates.

Ashby had two sons; one lost his life in World War II, the other survives. To Mrs. S. F. Ashby and her son, the Staff of the College offer condolence and sympathy at their loss. F. H.

Managing Agents in the Eastern Plantation Industry

Sir Eric Macfadyen
Harrisons & Crosfield Ltd., London

The Managing Agency system is an organic link between home capital and overseas enterprise in the Eastern plantation industry. Historically its roots go back a long way. As the East India Company's monopoly trade withered under the weight of the Company's governmental responsibilities, finally coming to an end in name as well as in fact in the period following the Napoleonic wars, private enterprise advanced to fill the gap. In all the main ports of the Orient merchant houses established themselves as agents for ship owners, as importers of textiles, machinery and Western manufactures generally, and as buyers of country produce to fill their ships' holds on their homeward voyages. Singapore, to take one example, grew during the first half of the nineteenth century from a mere fishing village into a large entrepot for east-west trade—a transhipment nexus whence local shipping routes radiated all over south east Asia—through the Straits of Malacca, the Dutch Indies, the thousand islands of the Malay archipelago and the China coast. As a free trade port it attracted trade in silks, spices, pepper, nutmegs, perfumes, fibres, minerals, hard woods, rattans, rice and innumerable minor articles. The main function of British sea power, throughout the long reign of Queen Victoria, was the policing of sea routes, and the British merchant community was the focus of all this commerce. Through such centres as Bombay, Calcutta, Colombo, Rangoon, Singapore, Hongkong or Shanghai safe and regular communications were made available to all who required them. The life-blood of the whole system was the bill on London, the cheapest and most effective international currency the world has known ; its framework was built upon the firms, with head offices in London, or it might be in Liverpool or Manchester, whose correspondents were established in these great trading ports.

With growing prestige and financial strength, and with ever expanding connections, it was natural that the Eastern merchants should seek to promote, by all means in their power, the productive capacity of the territories in which they operated. In some cases they fostered mining enterprise, but the chief wealth of these lands was agricultural. In the second half of the nineteenth century organized plantations for the cultivation of economic crops became, with their support, a leading feature in the prosperity of India, Ceylon, Malaya and other Eastern regions. Virgin land was there awaiting development : labour could be cheaply shipped from where it was superabundant to where new openings awaited it. It was only necessary for a marriage to be arranged between capital and opportunity for fruitful developments to follow. Certain of the merchant houses became the go-betweens and gradually there grew up under their

wing an extensive export of plantation-grown produce. Their successors are among the ' Managing Agents ' of today.

At the beginning of the reign of Victoria the only source of supply of tea to Western markets was China. Today a thousand million pounds of tea are produced in a year in India and Ceylon : the original capital for creating the industry having almost all been found in the United Kingdom. Rubber, which in recent years has been the sterling area's chief dollar-earning export—surpassing in value in some years the whole of the exports to U.S.A. of Great Britain's domestic production—was introduced from Brazil 80 years ago, *via* Kew Gardens. Indeed, the pedigree of the Eastern planter might be given as ' by Kew Gardens out of Younger Son ', for the typical tea or rubber estate began by being a family affair. A retired Anglo-Indian soldier or Civil Servant, having already provided one son for the Army and another for the Church, would ship yet another out East to start planting, under the wing of some old acquaintance established there. He began his career as a ' creeper ', or apprentice, a conventional fee of one hundred pounds being paid to the senior planter who undertook to board him for twelve months and teach him his job. Once a full-blown *sinna durai* (assistant), it soon became his ambition to set up on his own, and when he got leave, after five or six years probably in those days, he did his best to raise from among his family and their friends a couple of thousand pounds or so with which to start a small estate. The majority of the plantation companies whose names are familiar to the Stock Exchange investor today have grown from small beginnings such as this.

The Victorian era was high summer for the proprietary planter. Not a very great deal was required of him beyond the faculty of getting on with native labour. The man who was ' good with labour ', conscientious, and reasonably industrious, would get by. On the business side the agents in Calcutta, Colombo, or Kuala Lumpur whose London principals were in touch with the source of his capital would keep him on the right lines. They would arrange for a senior planter to visit him now and then, advise him on technical matters and report on his progress. They would send up-country his estate supplies, tools, *etc.* The work of opening a small estate was responsible but not exacting—he must drain and clear his jungle, line, hole, and plant out the seedlings he had raised in nurseries and then, for some years, watch their growth while keeping the gardens clean weeded until the plants reached maturity. When cropping started he sought his agents' guidance on processing it, for they had to ship it for sale by their London house. He lived an open-air life—mustered his labour force at dawn and supervised their tasks until afternoon. His day ended, as it began, early, and he had trained native subordinates to help him: so he was fully occupied but not overworked. He had to get used to a certain amount of loneliness, for social life did not amount to much: but he would probably get a good deal of sport and there would be occasional visitors and periodical gatherings in the nearest town. He belonged to a landed class and enjoyed a privileged standing. He might live to become something of a patriarch or, with luck, make enough to retire and spend the back end regretting the East.

The proprietary planter now belongs to history. The name of his old estate may be perpetuated in that of a company famous on the Stock

Exchange, but if he were to revisit the scenes of his youth he might find it a comparatively unimportant unit almost lost in a much larger organization. All forms of agricultural enterprise are subject to fluctuations of prosperity, and tree crops particularly so, owing to the time lag involved in adjusting their output to market conditions. When profits are good everyone extends his acreage. The outlook is very different five or six years later when overproduction brings prices down. After a time lag the cheapness of the product results in expansion of demand. A shortage ensues and the cycle recurs. The history of the plantation commodities has been one of periodical crises, some of them fatal. False starts were made—in India with indigo, in Ceylon with coffee, in Malaya with sugar. In tea and rubber the scale of the proprietary unit was too small to stand up to recurrent financial shocks. It was found that larger factories were more efficient. The spreading of overheads made for economy. Partnerships lacked elasticity and the limited liability company offered a more adaptable form of ownership. Adjacent properties consequently merged their interests, and when additional capital was required it was natural that the firm with which the estate was associated should take a leading part in raising it. Their stake in the industry significantly increased. Estate units became much larger and tended to group themselves under the leading agency firms. They were the channel through which new capital had flowed and their influence in matters of financial policy was found to work to the advantage of shareholders. The process of integration has made rapid strides in the last generation and continues. The larger agencies may still have under their care companies owning a thousand acres or so, but these are the exception and it is now fairly common for a company to own up to ten, twenty or thirty thousand acres, operated in a dozen or so units. The industry may be less rich in colourful personalities, but there is compensation in greater commercial efficiency. The prosperity of the agents themselves depends on that of their companies.

The running of a company which in its present form was first made public under the auspices of one of the agency firms, proceeds on business-like lines. Its board of directors will meet regularly at the firm's London office, where a specialized staff undertake the secretarial duties for a number of such companies. The board of directors will include men of Eastern experience and at least one representative of its agents. In any case it largely draws upon their advice and experience. The board lays down both planting and financial policy, and, of course, is responsible to shareholders. The investment interest has long been spread over a wide body of shareholders, many of whom have ventured their money on the strength of the reputation of the agents, quite as much as on the name of the particular company. There will be a large planting staff of all grades of seniority, appointed in the first instance in London, the members of which no longer spend a lifetime on one small property, but look for promotion throughout the whole of the agents' connection. They are paid by salary and commission, with proper provision for superannuation. The system meets two desiderata not on the face of things easy to reconcile. Financial strength is gained from the size of the undertaking. On the other hand field supervision remains primarily a matter of sound labour relations, which are basically

dependent on the personal equation. Workably sized estate units, grouped under relatively large agencies, are the typical pattern today. The agency groups themselves vary in size: the largest cover very wide areas, 100,000 acres and more in a single planting country and some agencies operate in more than one country. There are instances of old established Eastern firms which have developed secretarial and agency work so successfully that their original trading activities are now probably secondary. There are also instances of younger firms which confine themselves wholly to agency duties.

The secretarial staff in London has its opposite numbers in the estates department of the agents in the East, whose functions are to see that the policy of the board is translated into appropriate action by the staff on the estate. They confer with the estate manager in the preparation of his annual estimates of expenditure; and in transmitting them to London interpret and comment on them, guided in doing so by experience which is not limited to the particular estate in question, but extends to many others comparably situated. Once estimates have been sanctioned by the directors (the chief means in practice of asserting their control) it becomes the business of the East to see that they are worked to, or if for good reason they require amendment, that the necessary sanction is obtained. The estates department will receive and examine a monthly statement of all estate expenditure which it will forward to London with comments and explanations. It will have on its staff qualified accountants who maintain virtually a current audit of the estate books to ensure that these are kept accurately in the manager's office on the estate, and it will spare no trouble to help the manager in the discharge of his responsibility for controlling expenditure. So far as possible the head of the estates department will ensure that continuity is preserved in the allocation of the care of particular estates to the same members of his staff for a long period.

No member of the Eastern organization is of greater importance than the visiting agent who, in a large agency, will probably be a whole-time member of its staff, in a smaller one he may be a free lance. He is the planting expert—chosen for his practical success over many years as an estate manager. His periodical visits are red letter days in the manager's calendar, when every corner of the estate is jointly inspected, any deficiencies discussed, and the measures to be taken to meet them agreed. The practised eye of the V.A., seeing the work in progress at intervals of three months or so will see things that the manager, in daily contact, may have missed ; and if a critical report is called for, the V.A.'s visit is then a black letter day. It is from the V.A.'s report that the planting members of the board at home will derive an up-to-date picture of the estate. The V.A. himself is kept in touch, between visits, by a glance over the manager's fortnightly progress of work report, in which current labour turnout and costs are summarized.

The agents will secure for a manager the advice of a variety of specialist consultants: a botanist, a soils expert, or a plant breeder may be called in. A new factory is to be designed for the estate, or an extension made to an existing one. Labour accommodation is to be modernized; a major drainage problem tackled; a concrete bridge to be constructed. The guidance of consulting engineers will be obtained for the manager on all

these problems. An epidemic of fever breaks out and the regular medical officer is supported by the advice of an anti-malarial expert.

The directors will largely be guided by the knowledge possessed by the estates department of staff personnel in deciding on its allocation and promotion.

The modern estate assistant must learn to be a scientific agriculturist, a labour expert and something of a technician. The manager is a business administrator, often on quite a big scale. Many managers of rubber estates are responsible for expenditure running into some hundreds of pounds a day all the year round. They could not discharge their responsibilities adequately without an efficient organization behind them. A decimal point of a penny saved on the cost per pound of rubber production will turn a loss over the company's year into a profit: each penny a pound may, in many companies, provide a dividend of five to ten per cent. The agency system is the linchpin of the plantation industry as it is carried out in the East today. It offers a career to the competent planter, guarantees the estate worker good wages, and safeguards the investor's money—all three indispensable to each other. It is difficult to conceive of all the necessary functions being discharged more effectively or at less cost. The managing agency system, in fact, delivers the goods.

(*Received May 1954*)

The Sugar Cane Industry in Fiji

From the Office of the Colonial Sugar Refining Company, Ltd., Sydney, Australia

INTRODUCTION

In the Fiji Archipelago of over 400 islands, sugar cane is grown commercially on the two largest islands which lie between latitudes of 16° and 19° South and longitude 177° and 180° East—one of 4,000 square miles and the other of 2,100 square miles.

Both these islands are volcanic in origin and possess a number of high peaks which on the main island reach about 4,000 ft. in height and divide the islands into distinct wet (windward) and dry (leeward) zones.

Four mills are situated on Viti Levu, the main island—one in the wet zone with an annual rainfall of 117 in. and the other three on the leeward coast with the rainfall varying from 70–82 in. per year.

The only mill situated on Vanua Levu, the second largest island, is on the leeward coast and has an annual average rainfall of 85 in.

Cane crops between 1,200,000 and 1,400,000 tons are now being produced annually and crushed at the five mills mentioned above, which have a total daily milling capacity of 9,400 long tons. The crushing season usually begins towards the end of June and is completed in the early part of December.

The first record of commercial sugar production was in 1862 on the plantation system using native labour. Later, labour from India was employed under an indenture system which commenced in 1879 and continued until 1917, when the system ceased and shortly afterwards labour became scarce.

This situation led to The Colonial Sugar Refining Company splitting up its plantations into small farms averaging 10–12 acres each and leasing them to individual Indian growers. The Company now retains only eight plantations amounting to some 2,700 acres of cultivated land, and these are used largely for the purpose of training field officers and for experimental work.

The sugar cane crop in Fiji, therefore, is now produced almost entirely on small farms, mainly by Indians, although there is a small proportion of Fijians who cultivate about 6 per cent of the total area.

GENERAL FARMING SYSTEM

The Indian farmers grow much of their own food requirements—principally rice and pulse crops. The food crops are frequently grown on cane land fallows and, being an integral part of cane agriculture, thus determine to a large extent the crop cycle, the rotation of the cane lands and the time of planting.

In 1952, cane growers planted a total of 17,519 acres of rice. Of this area, 10,055 acres were on cane land fallows; most of it was planted to cane very shortly after the rice harvest. In addition, 38 per cent of the area planted with cane in 1952 had also been planted with a green manure crop.

Figure 1. An aerial view of the largest mill in the Islands

Figure 2. An Indian cane farmer ploughing-in a crop of Mauritius bean

Green manure crops formerly consisted of Mauritius bean (*Stizolobium sp.*), rice bean (*Phaseolus calcaratus*) or other long cover legume. With increase in population, however, the necessity has arisen to grow more food crops and the long term green manures have been replaced with quick maturing cowpea crops. The seed is usually allowed to mature and is picked for food. Cowpeas (*Vigna spp.*) are sown mainly in the spring or autumn but may be planted throughout the year except during the wet season. Dhal (*Cajanus cajan*) is usually grown on poor hillsides, and, being late maturing, if the land is also used for a cane crop, it usually misses one cane planting season.

The farmers are largely tenants, either of the milling Company or other land holders. A large area of cane land is owned by Fijians and is administered by the Native Land Trust Board. Some of it is leased to the growers, either direct by the Board or sub-leased as in the case of much of the leasehold land held by the Company.

The following table, for 1953, shows the average size of farm and the numbers of the several categories of growers.

Number of Growers and Area of Farms
1953

	Number of farmers	*Area cultivated (acres)*	*Average area per grower*		*Average tons of cane harvested per acre*
			Acres cultivated	*Acres harvested*	
Indian					
Coy's tenants	4360	49634	11·4	7·0	24·7
Independent suppliers	4837	45626	9·4	6·4	22·9
Fijian					
Coy's tenants	101	835	8·3	4·9	23·3
Independent suppliers	1222	5104	4·2	2·2	18·3
Other Races	23	330	14·3	8·9	21·0
C.S.R. Plantations	8	2634	329·3	189·8	26·3
Total	10551	104163	9·9	6·4	23·7

The average yield of cane for the period 1947–53 was 20 tons per acre, ranging from 16·2 tons per acre up to 23·6 tons per acre.

Cane in Fiji is of relatively high quality, and in recent years an average of 7·3 tons of cane have been required to make one ton of 94 N.T. sugar (approximately 97° pol.).

SOILS AND FERTILIZERS

The sugar cane soils of Fiji are derived largely from andesitic lavas and soapstones. The latter are not true soapstones but volcanic mud laid down under marine conditions. A few soils are derived from limestones and basalts but their area is small.

Most of the soils are alluvial. On the river banks and flood plains they consist of deep, free, fertile, sandy loams, but in the deltas the sandy loams are interspersed with heavy clay loams difficult to drain and cultivate.

Classified according to fertility, the sugar cane soils consist of about 20 per cent of rich land, 50 per cent of medium land and 30 per cent of poor land.

Generally speaking, the soils are badly leached and highly acid with a pH 5·1–5·8. They respond markedly to the application of lime, apparently not only because of an increase in pH, but also because of a deficiency of lime as a plant food. Limestone deposits are scarce, but deposits of coral sand are readily available at all mills except one. Coral sand is applied regularly to fields just before ploughing-out at the rate of 5–8 tons per acre about once every 10 years.

Certain areas are deficient in phosphoric acid, and superphosphate is applied at the rate of 2–3 cwt. per acre in the drill.

The soils appear amply supplied with potash and, to date, all trials with this fertilizer have given no response.

Except on certain very rich soils, nitrogen is markedly deficient. The usual practice is to apply 1 cwt. sulphate of ammonia to plant cane if a green manure crop has not been grown just previously, and 2–3 cwt. per acre to ratoon cane. The rate of application is slowly increasing.

Mud from the rotary filters is applied to fallow land at the rate of 20–30 tons per acre.

CANE CULTIVATION METHODS

The time of planting is not only affected by the wet season but also by the food crops grown on the cane fallows.

With the exception of one mill area, little planting occurs before March and it is not complete before July or even August. The hill lands are usually planted first, as they are drier and, by reason of the poorer soil, they require the longest possible period of growth.

The average area harvested during the period 1948–1952 consisted of 51 per cent plant cane, 44 per cent first ratoons and 5 per cent second ratoons. The crop cycle, therefore, consists essentially of a plant and first ratoon crop.

The plant crop is harvested during the first half of the season at the average age of 15 months and the ratoon during the latter half of the season at an average age of 13 months.

The grower's first consideration is to plant his rice crop. When this is planted on a portion of the cane fallows the trash on this area is usually burnt, but the trash is ploughed in on land planted to a green manure crop in November–December. In the period 1948–1952, the trash had been ploughed in on an average of 37 per cent of the land planted; 52 per cent of the land received a green manure crop—mainly cowpeas.

During the past two or three years, ploughing-out of cane stubbles by tractor instead of animal power has increased tremendously and much of the farmers' land is thus prepared. A number of farmers own their own tractors but, more usually, the operation is performed by contract ploughmen.

Where animal power is still used, the ploughing is done by either bullock or horse teams using a 10 in. mouldboard plough in the wet areas and by either a 28 in. disc or a mouldboard plough on the areas in the dry zone.

The land is tine harrowed, sown with cowpea and harrowed again. The cowpeas are allowed to mature, picked for food and green matter ploughed

Figure 3. Inter-row cultivation

Figure 4. Indian cane cutters loading trucks in the field. Trucks run on portable line to permanent way

in. The field is harrowed and usually receives a further ploughing and harrowing before planting with cane.

Cane rows are 4 ft. 6 in. apart. Drills are opened by passing twice up the same furrow in opposite directions with a single mouldboard plough drawn usually by a pair of bullocks. Superphosphate is applied where necessary in the drill.

The seed cane is usually obtained from the grower's own area. The trash is stripped off the whole stalks before they are placed in the bottom of the drill and there cut into setts 12–15 in. long.

The setts are spaced 4–8 in. apart in the drill with the eyes on a horizontal plane, pressed into the soil with the foot, and covered with soil to a depth of 1–2 in. either by hoe or with the hands.

Inter-row cultivation is carried out by such implements as disc harrows small 8 in. mouldboard ploughs and 5-tine scarifiers. The inter-row is worked, usually, four to six times before it is out of hand, some 6–7 months after planting, and about three hand weedings, using hoes, are usually given.

In ratooning, the plant trash is usually burnt as soon as possible after harvesting. This is followed by ploughing away from the cane row and later splitting the middles. The cane is given some two or three ploughings, scarified about the same number of times and given two or three hand weedings. In the wet zone sulphate of ammonia is applied as soon as growth commences, but in the dry zone, not until some 2–3 months after harvesting.

The practice of leaving the plant trash and merely relieving it from the cane row is increasing but is still very limited and is by no means a general method of ratooning.

Where the clay sub-soils are more or less impervious and drainage depends on surface removal, the trend is for the fields to be ploughed into lands, frequently cambered, about 66 ft. wide. Cambered beds are also finding favour in certain other limited localities in the dry zone where low-lying, stiff clay soils overlie impervious sub-soils which do not respond to sub-soiling or mole draining. In the dry zone more reliance is placed on hillside or catchment drains rather than on cambered beds.

CANE VARIETIES AND DISEASES

The varieties grown are almost entirely *S. officinarum* types. In the wet zone Malabar (Yellow Caledonia) remains the standard variety for the heavy clay soils. Argus (18R.1167) is also grown to a limited extent on clay soils. Badila (N.G.15) and Galba (25R.408) are the other varieties grown in that zone.

At the mills in the dry zone of Viti Levu Badila is grown on the rich soils, Galba on medium soils and Ajax (22R.226) and Pompey (7R.428) on the poor soils. On Vanua Levu H.109 and POJ.2878 are grown on the poor soils, Galba on the medium and Badila on rich soils.

Resistance to diseases has been the major factor in retaining the noble type canes. However, suitable hybrid canes are now becoming available and Eros (33M.Q.377) is being extended at two mills where downy mildew and Fiji diseases are not a decisive factor. Pindar (37M.Q.22) is being

extended at all mills, while Mentor (38R.9737), which is moderately susceptible to leaf scald, is being extended at three mills only.

In the 1953 season, the proportion of varieties crushed was:

	Per cent crushed
Badila	27
Pompey	28
Galba	16
Ajax	12
H.109	7
Malabar	5
P.O.J. 2878 ...	2
Argus	1
Others	2
Total ...	100

Three major diseases occur in Fiji, *viz.* downy mildew (*Sclerospora sacchari*), Fiji disease (virus) and leaf scald (*Bacterium albilineans*). The main control measure is the growing of resistant varieties, although supplementary control measures consisting of roguing diseased stools in crops and seed beds by trained gangs are of considerable value where the cane is infected by either downy mildew or Fiji disease.

Considerable agricultural experimental work and cane breeding is carried out by The Colonial Sugar Refining Company. The main experiment station, including the pathological laboratory, is situated in the dry zone at the largest mill. There are sub-stations at two other mill centres.

The main lines of breeding are the back crossing of forms of *S. spontaneum* on to varieties of *S. officinarum*; the inbreeding, by sib-mating and selfing, of vigorous varieties with high early quality and the production of varieties resistant to all major diseases. From 20,000 to 30,000 seedlings are planted out annually.

HARVESTING THE CANE CROP

The system developed in Fiji to harvest Indian and Fijian farmers' crops is a co-operative one, each farmer combining with his neighbours in a defined area to form a gang which operates throughout the whole or most of the crushing season to take off the whole of the cane crop in that area, in an orderly fashion and to the best advantage of the growers and the miller.

The annual cane crop, varying between 1,200,000 and 1,400,000 tons, is grown almost entirely by over 10,000 farmers supplying five mills which have crushing capacities ranging from 3,500 to 25,000 tons of cane per week. The crop grown by each farmer may be as small as 20 or 30 tons or as much as a few hundred tons, but the great majority on farms of 10–12 acres produce between 120 and 180 tons per year.

Mill cane areas are divided into sectors, each under the charge of a field officer, and in each sector two, three or more gangs are formed to harvest the crop. The area of each gang's operations is fixed, having regard to

natural well defined limits wherever possible, the distance members of the gang have to walk or ride to and from work, the availability of portable line and the most easily workable size of the gang.

Every grower in a particular gang area must either join that gang to work himself or provide a substitute. Their racial differences or their affiliation with any of the various growers' associations naturally cannot be taken into account; this is on the whole an advantage in that it brings growers of one locality together and tends to prevent individual or party differences from becoming wider. A gang may comprise as many as 60 growers in a compact locality to as few as 15 or 20 in a scattered area.

The mill owner provides portable line which enables trucks to be taken to any point in the various fields and, after loading, to be hauled out again to the permanent line. Earnings of each man in the gang are computed by the gang's headman and checked by the field officer; the actual amount required to pay the members of the gang fortnightly is advanced by the mill owner and payment is made in the field.

The field officer, under the district superintendent, exercises general supervision of the gangs, makes arrangements for trucks, portable line and other facilities, and decides (usually in consultation with the headman) on the order of harvesting, having regard to the ripeness of the cane at least in the first part of the season.

Each grower provides manpower to the gang according to the estimated or actual tonnage of his crop. Modifications have been made to the harvesting agreement in recent years to suit changing conditions and a reciprocal wages method is now widely used for the determination of a grower's quota of manpower to the gang. With this method a grower's own earnings in the gang must approximate what it has cost in wages paid to the gang to harvest his cane.

A grower with a small crop may need to work only a small part of the season, others with bigger tonnages may have to provide a full season unit, plus a man for part of the season, or perhaps up to two or three full units of manpower for the season; the requirements depend on the size of the individual's crop. Nowadays, about half the growers engage substitutes to work in the gang on their behalf.

Gangs normally harvest a daily quota of cane right throughout the crushing season, which lasts five to six months. With proper co-ordination the gangs, by cutting their correct quantity of cane each week, usually all finish off evenly at the end of the season.

That the system works efficiently is demonstrated by the fact that cane is seldom, if ever, left unharvested and rarely are the mills slowed down for lack of a sufficient supply of cane.

TRANSPORT OF CANE

The millers maintain 410 miles of 2 ft. gauge permanent tramway, 42 miles of horselines, 164 miles of 14 lb. portable line, 46 steam locomotives, 17 internal combustion locomotives, 6,400 cane trucks, 14 launches and 77 cane punts. The five mills have a capacity output of approximately 180,000 tons of sugar in a 162-day crop.

One of the smaller mills uses both punts and trucks, while the other four mills use only trucks for the transport of cane. The small proportion of

cane grown beyond the normal cane perimeter is hauled by motor lorries to the nearest point on the main line and then loaded on to cane trucks.

In the case of water transport, the punts to be filled are delivered to suitable points along the river and the cane is loaded from trucks hauled from the field along portable line.

The rail transport system operates by locomotives delivering the cane trucks at the nearest point on the main line, branch line or loop. The deliveries are usually made to the cutting gangs during the forenoon. The inward and outward haulage to and from the field being harvested is done mainly by bullocks. The locomotives take delivery of the loaded trucks on the permanent line in the late afternoon or during the night.

Apart from the various expansive river valleys, the cane areas are confined to the narrow coastal strip and extend many miles from the mill, with the longest haul being just over 80 miles. Average haulage distances at the five mills vary from 4½ miles at the smallest to 27 miles at the largest mill.

Most of the locomotives are operated on a two shift basis over a single line with adequate loops as passing points. Running control from the mill centre is maintained by a telephone line alongside the permanent line with telephones at appropriate intervals.

Cane trucks of the side tipping type weigh from 10–12 cwt. each and carry 2½–3½ tons of cane secured by a central chain.

There are a few steep grades to be climbed, but for the most part the track is on level ground or has an easy gradient and the larger 15–17 ton locomotives haul gross loads of about 280 tons.

FIELD ORGANIZATION

The effective operation of the small farm system depends to a large extent on the organizational and supervisory services supplied by the sector field officers who are responsible for an area occupied by between 150 and 200 farmers. Amongst the many duties of the field officer are those of determining the variety of cane suitable for the field which is to be planted, advising on cultivation, maintaining the main drainage system with organized gangs of farmers, seeing that diseased cane is rogued, arranging cash advances for the farmers, providing supplies of coral sand, mill mud, fertilizers, farm requisites, *etc*, organizing and paying the cane-cutting gangs and making payments for cane.

The field officer is usually an officer of many years' experience in the industry in Fiji. He has had training in cane cultivation and growers' affairs generally and understands Indian and Fijian customs and language. He resides with his family in the midst of the cane growers in the sector and maintains direct contact with them. In their working hours they are closely associated—much of the mutual trust between the grower and the mill owner stems from this association, and is an acknowledged feature of the industry. Under these circumstances, the cane grower knows he can depend on the field officer for much assistance and guidance regarding cane cultivation, harvesting matters and, in many instances, his private affairs; also the field officer can usually depend on the co-operation of the grower in the general organization of industry in the sector.

(*Received May 1954*)

Development of Mechanized Farming in Uganda

(*Reprinted, by permission, from the Official Bulletin of the Uganda Protectorate, March 1954**)

INTRODUCTION

The present African farming system in Uganda, except in one or two areas where the inhabitants are pastoralists subsisting on cattle and cattle products, consists in the main of individuals or groups of families engaged in arable farming on a semi-subsistence basis. Cattle are relatively few in number and livestock takes but little part in the farming set-up. Agricultural production is based on a peasant farming foundation, and its objects are to produce food and cash crops to satisfy the need of the family unit. Little or no attempt is made to improve the poorer land or to improve the grazing of resting land or permanent pasture, and the present methods can be regarded as wasteful of land and energy.

Agriculture will in the foreseeable future remain the main industry of the country and the only means of livelihood for the majority of its inhabitants; it is inevitable therefore that agricultural production should remain based on a foundation of peasant farming. But to say this does not imply that there will be no place for the development of larger individually-owned farms on which labour may be employed, or that the soundest line of advancement is not the development of group production among groups of peasants. Indeed, such systems, which involve reorientation of holdings, will be necessary for proper and efficient use of the land and from the point of view of land utilization there is no basic difference between the land being properly farmed by an individual owner operating on a large scale or by a co-ordinated group of peasants working for themselves under group leadership. The purpose of this brief preamble is to draw attention to one of the central problems with which mechanized agriculture is faced. Independent holdings with their small fields and haphazard layout are not conducive to economic methods of mechanized farming which require fields of a reasonable size, about 20 acres being the optimum. In considering the development of mechanized farming, therefore, it is necessary to get away from preconceived ideas and to avoid so far as possible the pitfalls of a strictly individual family farm economy. Provided there is a re-orientation of farm layout, the use of machinery should increase production per unit of labour in various ways. It can permit land operations to be carried out quickly at the right time ; it can make possible the easy application of dusts and sprays for insect and disease control ; the application of manures and fertilizers becomes more feasible and great economies can be effected in such operations as thrashing, grinding or gristing, marketing and farm transport.

* This Bulletin is printed for official circulation only, and is not on sale to the public.—*Ed.*

Notwithstanding the apparent advantages of mechanization, machinery will only be used on the land if the return obtained by the farmer through its use is greater than that which he could obtain by following traditional methods. Unless this economic advantage is clearly demonstrated, there will be no desire on the part of African farmers to regroup and to consolidate fragmented holdings so that they can take advantage of mechanization and at the same time effect better utilization of the land.

No one system of agriculture can have general application throughout the Protectorate. Since 1948 investigational work has been carried out in different areas varying from the densely populated areas of Buganda with its heavy fertile soils and well distributed rainfall, to the extensive areas of the Northern Province where the population is comparatively sparse and soils are light and the natural vegetation cover is less dense. The investigational schemes fall into two main categories:

(*a*) Those in inhabited areas which are already cultivated under traditional farming systems. These may be sub-divided into:

(*i*) Fairly thickly populated areas where there is a preponderance of permanent crops (*e.g.*, parts of Buganda).

(*ii*) Fairly thickly populated areas where annual crops are predominant (*e.g.*, Teso).

(*iii*) Areas of new settlement where an endeavour is being made to organize land use as settlement takes place (*e.g.*, Lango, Acholi and the western parts of Buganda).

(*b*) Those in areas which, on account of tsetse or lack of water supplies or other factors, have been uninhabited. At present there are two such schemes operated by Busoga Farms and the Bunyoro Agricultural Company.

SCHEMES IN INHABITED AREAS

Method of Operation

The main method by which investigation has been carried out into the use of machinery and the reorganization of peasant holdings is through contract work done by the Agricultural Department for farmers in selected areas which are representative of those mentioned above. Since 1948 the number of tractor outfits employed on contract has increased steadily and there are now 25 in Buganda, nine in Lango and Acholi, four in Bunyoro, two in Teso, two in Busoga and three in Toro. Contract work is carried out by the Special Development Section of the Agricultural Department under the supervision of the Assistant Director of Agriculture (Special Development). Detailed records are maintained of tractor performance and costs. All tractors are fitted with hour recorders and the results are analysed at the Section's headquarters at Kawanda. The accounts of the Buganda units are kept on a commercial double entry system under which depreciation and supervisory charges are included; and the method of keeping accounts enables comparisons in cost to be made not only between different types of tractors and implements, but also between different areas. During the 1953 season these results were analysed by an Agricultural Economist loaned by Makerere College, who is also carrying out field surveys to study the effect of mechanization on farming systems.

The hiring rates which have been charged in Buganda in 1953 have varied according to the total contiguous acreage which has been offered for cultivation under any one contract, thus for ploughing areas of 10 acres and over a charge of Shs. 32 per acre has been made, whereas for ploughing an area under two acres the rate has been Shs. 52/50. This has been done to encourage farmers to group their fields into larger units more suitable for economic mechanical cultivation. Charges in Teso, Lango and Acholi in the same period were about 10 per cent lower because of easier ploughing conditions. As explained below in the section dealing with contract service costs, the charges have been increased since 1 January 1954, by about 50 per cent.

Machinery

The tractors mainly used are Fergusons and Fordsons. Trailer disc ploughs were originally tried but they are now being replaced by mounted disc ploughs which are proving more satisfactory. For preparing land for seeding disc tillers and rotavators are proving successful on the light and heavier soils respectively. Cotton and maize are being planted satisfactorily with both mounted and trailer planters, but as the minimum row width on these is 28 in., they are not so suitable for such crops as groundnuts, beans and soya beans. Trials are, however, in progress with a prototype planter with a minimum width of 18 in. which should prove more suitable. Eleusine (finger millet) can be planted successfully with either the 'Bean' seeder or a seed drill. Trials with various types of weeding equipment have been made but none has yet proved satisfactory or popular, as farmers can normally weed more cheaply by hand. Contract harvesting has not yet been carried out although it has been proved on the two development farms in Busoga and Bunyoro that finger millet is capable of being harvested successfully with combine harvesters.

Other equipment used extensively with the tractors is the two-wheeled low-loading trailer which is used for transport of equipment from farm to farm and occasionally for contract work in connection with farm haulage.

It has been established that owing to the different and more difficult conditions pertaining in Uganda the implements required for mechanized agriculture are not the same as those which have been successful in more developed countries. In few cases has the manufacture of special equipment proved necessary; modification and strengthening of existing machinery is normally adequate. But although the types now available are much more satisfactory than they were two or three years ago, progress is still limited by the lack of suitable equipment.

Farm Organization

Where population is dense and there is a preponderance of permanent crops such as coffee and bananas, progress has been slow and there has been little or no radical change in farm layouts. Farmers are not prepared to leave their homes in order to start mechanically assisted farming in vacant areas. In Buganda the mailo system of land tenure has proved to be an added difficulty. Further, operational costs have been high because of the small size and more scattered nature of the fields. Nevertheless, some changes in farm organization have been made and while as

yet the use of machinery in coffee farming is not generally practicable, many farmers are hiring tractors to open up land which they intend to plant with coffee or bananas after one or two years under annual crops. In the less thickly populated areas it is clear that mechanization is providing a strong stimulus both towards group farming by smaller farmers in order to achieve a more efficient layout of their land and also towards improving the layout and development of larger farms. It is interesting to note that some of the most successful schemes are in areas where group farming is developing under the existing indigenous systems of tribal organization in which some form of communal land use is traditional.

In brief, mechanized agriculture is proving most promising in those areas where tractor outfits have been able to operate for as long as possible within a small radius of their base or where the fields are reasonably large and where there is sufficient family or paid labour to undertake weeding and harvesting. It is too early yet to say whether mechanization is increasing the efficiency of production in terms of crop yields per acre, although there is a tendency in that direction through the opportunities which it is providing for earlier and better land preparation and for taking advantage of optimum planting conditions; but it can certainly be said that mechanization has increased production per man by making it possible to cultivate more acres even if the yield per acre has not been increased.

Contract Service Costs

Costs vary between different areas, but they have always been found to be extremely high for at least the first two years until farmers have adapted themselves to the use of tractors and until the organization of the units has settled down. In Buganda in 1952 average running costs of ploughing ranged from Shs. 30 to Shs. 48 per acre, and full costs including depreciation and supervision from Shs. 60 to Shs. 90 per acre. In Lango and Acholi full costs were in the region of Shs. 45. The best results have been achieved where the arable areas have been consolidated either on individual large farms or by regrouping smaller farms. Analysis of records has shown that the average running costs of tractors employed on contract schemes are 60 per cent higher than similar costs on experimental and development farms. The main reasons for this are the lower number of hours worked annually by contract tractors because they must move from farm to farm, and higher expenditure on spares and repairs, of which tyres are the largest item. Even in the most favourable conditions where a tractor is operating within a radius of about two miles of its station the full cost of ploughing is between Shs. 40 and Shs. 60 per acre, which is still higher than that on experimental and development farms; but the difference is caused (*a*) by the shortness of the contract season, and (*b*) by high supervision charges when machinery is operated from a unit headquarters many miles away. These extra costs are believed to be inherent in any contract hire service. On the more successful schemes the average receipts have been about equal to the average running costs (without depreciation and supervision) and although better results will no doubt be obtained in future the contract charges have been raised since 1 January 1954 by about 50 per cent.

SCHEMES IN UNINHABITED AREAS

Two development farms have been established, the Busoga Farms in 1949, and the Bunyoro Agricultural Company in 1950, with the object of investigating in different types of country farming methods and systems of land utilization under a high degree of mechanization. Busoga Farms are in a rain forest area where clearing costs were high and where capital investment of about £50 per acre was required to cover this and housing, machinery and initial development charges. The soils are fertile and after they recover from the disturbance of clearing and stumping, which normally takes two seasons, they give high yields of bulk food crops, such as sweet potatoes, maize, groundnuts, finger millet and sorghum, and also cotton. Results so far suggest that a highly mechanized system of farming depending on these crops does not give a return sufficient to justify the high capital investment; and further investigation is being made into the possibility of changing the system from estate farming to the introduction of tenants together with a lower degree of mechanization.

The Bunyoro Agricultural Company was established to open up an almost uninhabited tsetse infected area, of which some 30 square miles have been assigned to the Company. The scheme is, however, being confined at first to the development of an area of about 2,400 acres which is regarded as a pilot scheme. In the first instance the land is being developed on an estate basis; but the aim is to establish a tenancy system with the Company providing mechanical cultivation, crop processing services, and assistance with water supplies and other utilities. Vegetation is low dense bush and clearing costs have been much lower than Busoga. In addition to crops such as maize, groundnuts and eleusine millet, flue-cured tobacco is being grown and the success of the scheme will depend on the ability of the latter, which is relatively high-priced, to produce a profit sufficient to cover costs. A reasonable assessment of capital costs has not yet been possible, but owing to the high costs of buildings for tobacco they will probably not be much lower than those of Busoga Farms.

FUTURE DEVELOPMENT OF TRACTOR HIRE IN INHABITED AREAS

The results of investigational work on the hire of machinery for various farming operations and on the reorientation of land holdings have been sufficiently encouraging to consider what the next stage of development is to be. It has always been visualized that after the pilot stage the provision of a mechanized cultivation service should pass from the Agricultural Department to an organization which is more on the lines of a commercial undertaking rather than that farmers should be encouraged themselves to purchase their own equipment either individually or co-operatively, because apart from the difficulty of finding the necessary capital farmers would not initially have the experience required to operate and maintain their machinery. The next stage, therefore, is to convert investigational schemes where they have proved to be successful into commercial undertakings, and this is now receiving active consideration. The Agricultural Department will of course continue to carry out investigational work in those areas where existing schemes have not yet proved to be successful.

(*Received May 1954*)

The Teaching of Tropical Agriculture in Europe—IV: Italy

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INTRODUCTION

In an overpopulated country like Italy with a limited territory, mainly hilly or mountainous in character, problems relating to the finding of work abroad are of fundamental importance in connection with the standard of living, social welfare, and political stability itself.

The advisability of creating a school of tropical agriculture in Italy began to make itself felt at the beginning of the century, owing to the development of agricultural emigration and to the beginning of an African policy.

Agricultural emigration was mainly directed towards tropical and subtropical countries in South America. With regard to Africa, its first results in Eritrea and Somaliland emphasized the importance and difficulties of a sound scientific and technical training of government personnel to undertake agricultural services in those countries, as well as the problem of a sound basic policy for private agriculturists.

We therefore thought it opportune to offer to all those who wished to go to the tropics (technicians, agriculturists, and those interested in economics) the possibility of obtaining a suitable training which would facilitate their adjustment in those countries.

An endeavour of this nature proved of slow, complex, and difficult development in a country like Italy, without experience and tradition and with only a short history of independence.

The Italian centre of tropical agricultural studies, under the title of Italian Colonial Agricultural Institute, was established in Florence in 1904, by a group of travellers and scientists and through the personal initiative of Dr. Gino Bartolommei Gioli, and was devoted to teaching.

Many years later some specialized courses for a doctorate in agriculture were organized by the agricultural faculty of Portici (Naples), and yearly courses on tropical agriculture, as an optional and subsidiary subject, are held in certain universities of the Republic.

THE INSTITUTE OF OVERSEAS AGRICULTURE, FLORENCE

Florence was not chosen as the site of tropical agricultural studies for any compelling reason. What contributed to it, apart from its position in the centre of Italy, was doubtless its excellent training and teaching, especially in the agricultural field, which envisaged a constructive collaboration between scientists and specially qualified men of action that did, in fact, take place. Florence—with its university faculties of agricultural science and forestry; with its technical agricultural institute specializing in fruit, horticulture, and gardening; with its national experimental station for

silviculture; its experimental institute of agricultural entomology; its botanical institute possessing the largest herbarium in Italy with a colonial herbarium attached; its recently-created experimental institute for soil conservation; its Georgofili Academy of Agricultural Economics—constitutes the chief centre of agrarian studies in Italy, and is therefore specially suitable for the growth and development of research on tropical agriculture.

During the course of years the Institute has been modified several times and from 1939 onwards it became a state organization, controlled by the Ministry for Italian Africa. It discharged certain functions in conjunction with the agricultural services in Africa. On the suppression of this Ministry the Institute passed under the control of the Ministry for Foreign Affairs and is still in course of transformation into an Institute of Overseas Agriculture (Istituto Agronomico per l'Oltramare).

From the beginning, a linking of its teaching activity with research and technical advisory work appeared advisable. Financial reasons suggested, and up to a point imposed, such a policy, which may appear unsuitable, especially when dealing with the training of specialists.

The heavy tasks arising from the creation of a specialized body in tropical agriculture, the difficulties to be overcome in order to have available a suitable corps of teachers, and the care which the various services would have required to ensure their efficiency, all made concentration into one single institution of all possible national requirements relating to such overseas work, appear advisable.

This basic policy enables the Institute to be considered not only as a school providing for the teaching of tropical agriculture and similar subjects enabling technicians with a degree and those in possession of a diploma to receive cultural, technical, professional, and psychological preparation for activity abroad, but also as a centre for research, advisory, and technical assistance.

One can get a clearer idea of the activities of the Institute from its structure. It possesses the following scientific laboratories: agriculture and tropical crops, rural economy, chemical technology and agrarian industries, agricultural zoology, plant pathology, and agricultural entomology.

It also has available an advisory service and technical help for rural emigration, a service of scientific, technical and economic documentation, a publications and propaganda service, a specialized library of about 48,000 volumes, a photographic library, extensive collections of animal and vegetable products from tropical and sub-tropical countries, a farm for outdoor work, and hothouses for the collections of tropical plants.

In Italy's new international position the advisory duties of the Institute are of special importance with regard to the various technical, economic, and social aspects of rural emigration to different parts of the world. Such duties not only affect government departments but also those private citizens who wish to receive information and advice. Hence the Institute represents a base for Italian agricultural workers abroad.

GENERAL TEACHING WORK

The teaching activities of the Institute involve not only teaching at university level, but also 'upper middle' level; special short courses on given aspects are also held at irregular intervals.

A metropolitan school of tropical agriculture must not have the limited objective of training young specialists only in the practical field, or in this or that agricultural line, or in the starting and working of definite types of industry common in the tropics, but it should rather aim at imparting to those who wish to undertake scientific or professional work in the tropics, general information on various subjects to ease and accelerate their adjustment in the new country.

In the two basic courses, at university and upper middle levels, accepted students, doctors in agricultural science or in forestry or ' periti agrari ', have already followed regular courses dealing specifically with the biological, agricultural, and economic aspects of temperate countries. Specialized teaching is added to this basis, avoiding as much as possible useless repetitions and emphasizing instead the deep differences between areas in the inter-tropical belt, the problems they present to the technician, to the agriculturist, to the planter, to the forestry worker, and how such problems should be faced and resolved. There are data of a specially formative character which should be acquired before taking up work in the tropics. This information can be extremely valuable, enabling students to acquire a clearer view of the various problems and a realistic approach to them.

The tendency to apply to the hot regions of the globe knowledge and experience peculiar to temperate countries is very widespread. It constitutes a frequent source of error, which this school can very widely reduce. It is one of the duties of the teachers to be able to put together all information of a formative value to facilitate a rapid and smooth scientific and professional adjustment to tropical agriculture.

The other aim which is sought in Florence during the courses is a knowledge of the students, their character and qualities and their outlook on life in the tropics.

The fact that university and upper middle level teaching should be taking place at the same time in the same Institute may be a source of surprise, but its character as a specialized school suggested this policy of fusion, as apart from reasons of economy, it requires a special constitution and a body of teachers kept in close touch with the problems of the tropics.

The training of specialists in the various branches of agricultural science is not undertaken by this Institute.

TEACHING AT UNIVERSITY LEVEL

Over a period of many years the Institute held occasional short courses for doctors in agriculture, and others for those holding veterinary qualifications. Teachers from various Italian universities took part in these courses.

It was only later that the higher level studies for doctors in agriculture and in forestry took root. A special convention between the University of Florence and the Institute fixed the syllabus in 1939 on a permanent basis, establishing that the post-graduate course should be held annually in collaboration with the agricultural faculty of the University. Foreigners holding the necessary qualifications may be admitted.

The course lasts one academic year and the following subjects are taught : plant and animal geography, agriculture and tropical crops, tropical silviculture, rural economy, animal husbandry, the technology of tropical

products and agrarian industries, rural engineering, agricultural entomology, plant pathology, hygiene and first aid.

The teaching staff is represented by professors of the Institute and those from various university faculties.

Students must present a thesis on a subject discussed and agreed by a committee of professors, after they have passed their papers in individual subjects.

At the end of the course a post-graduate diploma in tropical agriculture is granted.

Enrolments during past years are as follows: 1946, 27; 1947, 21; 1948, 11; 1949, 14; 1950, 13; 1951, 17; 1952, 20; 1953, 15. Only a proportion of those enrolled obtained the diploma.

TEACHING AT UPPER MIDDLE LEVEL

During the first fifty years of the life of the Institute, the courses of teaching at upper middle level were also modified at different times. Three different stages stand out. (1) Optional instruction in three-year or two-year courses, with enrolment open to possessors of an upper middle level certificate. This did not permit the granting of certificates recognized by the State. (2) Teaching in the Institute becomes part of the State-provided upper middle teaching with two courses (*a*) 4th and 5th years of the Technical Agricultural Institute, specializing in tropical agriculture, and leading to the qualification of 'perito agrario', and (*b*) an annual course specializing in tropical agriculture, for 'periti agrari', leading to a specialist diploma. (3) Abolition of the 4th and 5th years of the Technical Agricultural Institute; upper middle level teaching limited to special course in tropical agriculture for 'periti agrari'.

The third stage, which is the present one, began in 1951 and was required in order to lighten the duties of the Institute in the field of technical teaching as a whole and in order to concentrate more on specialization.

The subjects taught are: tropical agronomy and agriculture, rural economy, animal husbandry and hygiene, technology of tropical products, taxonomy and plant pathology, specialized agricultural zoology, hygiene and first aid, foreign languages.

The course lasts one academic year. On completion of their studies, students have to take the State examination for specialists in tropical agriculture which qualifies for a diploma.

Numbers of students were as follows: Higher course of the Technical Agricultural Institute, diplomates: 1947, 27; 1948, 17; 1949, 3; 1950, 18; 1951, 14; 1952, 8; 1953, 7. Specialist courses for 'periti agrari': 1952, 12; 1953, 11; 1954, 5.

SHORT COURSES

Apart from routine teaching it is sometimes necessary to organize special short courses for technicians and agriculturists who require a general background for specific problems, for scholastic, cultural, or more often professional reasons. In the past many similar courses were held by the Institute in order to give a practical training to those wishing to undertake work in Africa.

Successive study groups have been organized on the problems of rural migration to those countries which particularly concern Italy; for example, special courses have been held for those intending to emigrate to farms in Brazil and the Argentine Republic. The abundant and up-to-date literature available at the Institute makes it possible to give those attending a real insight into the various problems.

More recently the Institute has collaborated in the development of special courses of instruction for Somali students who intend to become Civil Servants or teachers in their own country.

There are many, including agriculturists, technicians, missionaries and research workers, who on the eve of their departure for the tropics, or in pursuance of research, apply to the Institute or come to Florence for the necessary time, to obtain news, information, advice, or to collect the necessary data for their work. This service is much appreciated by those concerned.

RESIDENTIAL COURSES AT DEPARTMENTS OF THE INSTITUTE

Free residential periods in the various departments and laboratories of the Institute can be arranged for students and Italian and foreign scientists who wish to complete definite post-graduate studies under the supervision of the scientific staff of the Institute. In the past, while Italy had administrative responsibilities in Africa, many foreigners were guests of the Institute.

Foreign students may be interested to know, as recent experience shows, that it is possible for them to make use of the help offered by the Institute during their stay in Italy, for the special study of Italian rural economy or of other aspects of Italian life. At the beginning the foreign student is put in touch with the people and departments who can best help him and is able to consult the relevant books; he afterwards receives what help he requires for intended visits and trips. Problems related to land reclamation and agricultural settlements (being developed in various parts of Italy) are at present of special interest.

APPOINTMENTS FOR TECHNICIANS IN TROPICAL COUNTRIES

Only some of the technicians, at the higher and upper middle levels, who are completing their studies at the Institute, show any desire to undertake work in the tropics; the others follow the courses to increase their scientific knowledge prior to taking up professional posts in Italy.

Amongst those desiring to go abroad only a small proportion are able to do so freely at the request of friends and relatives already occupied in the tropics; these specialists generally include some who have funds available for investment abroad.

There is then the larger group who would like to work overseas but are not able to do so without the help of the Institute or of other bodies dealing with development in tropical countries.

Those wishing to embark on a professional career can win a bursary. This method has given good practical results. The technician chosen by the Institute is able to work for a period of one to two years in the tropics, helped financially by societies, by private individuals, or by government departments; he then is able to find a permanent post. Such bursaries were easily

won while Italy had territory in Africa. The problem is much more difficult now. Nevertheless, the Institute is able to send abroad a small number of trainees. Somaliland also is able to receive a few technicians, graduates and diplomates.

CONCLUSION

We may say in conclusion that the problem of the teaching of tropical agriculture in Italy is still of interest notwithstanding the loss of the African possessions. A smaller number of candidates than before has enrolled for the specialist courses taking place annually at the Institute in Florence. This must not be taken as implying that fewer students wish to make a career abroad, but rather as the result of the increased difficulties to be faced in finding a suitable post in the tropics.

In the new atmosphere of international collaboration which is trying to take root in Europe, which has many convinced sponsors in Italy, it might be possible to remember the wishes of Italian technicians to take part in agricultural schemes being planned or in actual development in the tropics. Even if only a small number of technicians could benefit by such an arrangement, the fact would be of special importance and of great help to the movement for a linking-up of Europe.

The Institute of Overseas Agriculture of Florence would be honoured if it were able to contribute its modest share to the realization of such plans.

(*Received July 1954*)

Crop Forecasts and Estimates with Particular Reference to Permanent Crops in the Tropics

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GENERAL CONSIDERATIONS

Purpose

Accurate forecasts of crops are useful for many purposes. They are particularly so in tropical peasant countries in which the farming community is mainly illiterate and where a small number of cash crops contribute a large percentage of the national income. Government will find use for the data for revenue purposes, the banks to calculate their currency requirements at buying centres, the road transport, rail and shipping interests to dispose their vehicles, rolling stock and ships, and the marketing agencies in connection with handling, provision of containers, storage, *etc.* In all cases the distribution of the crop over the season, as well as the total yield, will be of interest. Market intelligence will be improved and false information corrected.

A common principle of the Marketing Boards which have been set up in recent years is the ironing out of the violent fluctuations in farmers' incomes by fixing prices for a season on the internal market and building up price stabilization funds. The partial stabilization of a farmer's real income is necessarily dependent on control of prices of some of the goods he buys as well as of the produce he sells, whereas the stabilization of his money income is dependent only on his production and the produce price level. In either case the Marketing Boards are directly interested in both immediate season forecasts and long-term forecasts of production trends.

Permanent and Annual Crops

For several reasons this paper is confined mainly to permanent crops although there are some problems common to all crop forecasting. Annual crop forecasts and estimates are largely problems in sampling technique and there is already a mass of published material on the methodology and statistical analysis. Apart from the mathematics involved it is the relatively easier sector. Permanent cash crops, on the other hand, are a prominent feature of tropical agriculture under both the capitalized and the peasant plantation systems, and there are very few published reports on the subject of permanent crop estimates and forecasting.

Components of Production

The total yield of a crop is the product of its acreage and its average yield per acre. The first factor may be known, although this is rarely so in tropical agriculture, but the latter factor, yield per acre, must necessarily always

be subject to estimation. In developing a forecasting service the factors will be found to be inter-dependent : objective estimates of yield per acre obtained from sample plots in one season will, if the total outturn is available from market sources, provide estimates of acreage under crop, and these acreage estimates will, in turn, with future forecasts of yield per acre, provide future crop estimates.

YIELD PER ACRE

That yield per acre is a major factor is obvious from the very wide fluctuation in production of many plantation crops in different countries. Differences as high as 50 per cent are recorded. The crop may be harvested over a period of a few weeks only or extended over practically the whole of the year. With extended period crops, the seasonal distribution may be closely correlated with the seasonal distribution of rainfall and show two distinct peaks, near to the equator, corresponding to the major and minor monsoon-type rainy seasons. The study of the distribution is therefore important, as part of the fluctuation is not infrequently explained by the failure of the ' minor ' crop.

Another important component is the actual constitution of the crop itself. In cocoa, for example, crop yield is generally expressed as weight of fermented cocoa beans. The weight of dry beans will depend, apart from processing, on the size and number of beans in a pod, the number and size of pods on a tree and the number of trees per acre. Within each of these factors there is a wide distribution. The pod value (weight of wet beans per pod) is not a constant for pods on one tree. The monthly average value varies within the season and between seasons. Different trees have different average pod values, not necessarily correlated with size of tree, but dependent on many factors such as age of tree, type, soil and other topographical conditions. A high pod value may be found with a low total number of pods, and high negative correlations for individual trees are commonly found. The number of pods and therefore the individual tree yields also show wide variation.

For copra, the size of the nut and the thickness of the flesh of the coconut which together determine the ' number of nuts per ton of copra ' value, are the yield constituents. These examples could be multiplied but it is sufficient here to note that the exact constituents of the crop must be known as they provide variable factors which may be used in estimating and forecasting total yield. The variations will be extreme in peasant plantations raised from heterogeneous seedling stocks. In some Gold Coast cocoa farms I found that the lower 40 per cent of the trees provided only 13 per cent of the crop, whereas the upper 40 per cent provided over 70 per cent of the crop.

A third factor which must be studied is the development of the crop from the growth curve of a single fruit. The shape of the growth curve is as shown in *Figure 1*.

The curve can be established by taking observations at weekly intervals throughout a growing season from flowering to ripening of fruit. The linear dimensions, length and breadth, volume by displacement, shape,

colour, *etc* will have to be recorded over a range of conditions and for several seasons before the average standard curve can be established.

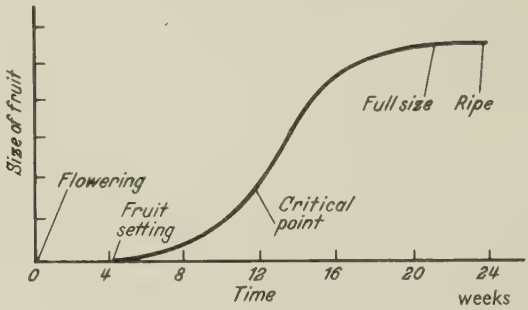

Figure 1. Autocatalytic or growth curve

More accurate linear measurements may be made by the indirect method of taking photographs from fixed points, using a suitable grid on the enlarged print to read off the dimensions of a number of fruit. This method obviates the risk of damage to the fruit by the repeated handling required for physical measurements. Volume can be computed from the length and breadth measurements. In cocoa the pod shape approximates to that of an oblate spheroid, whose volume is given by the formula $(\pi lb^2) \div 6$, where l and b are the length and breadth respectively. Occasional actual immersion volumes may be taken to calibrate the computed volumes.

One season's observations, however, will provide a good working knowledge of the age–size classes for the fruit, and enable a preliminary recording scheme to be worked out. From the growth curve it is possible to set out a time series, giving the size of the fruit at successive stages in its life history, as shown in *Figure 2*. These data form the basis of one method of crop fore-

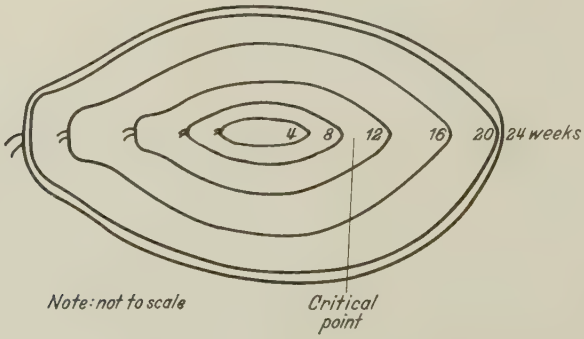

Figure 2. Size classes of cocoa pods in 4-weekly periods

casting, by making visual counts of fruit on the trees in various stages of growth and projecting the counts to ripe fruit in subsequent periods. The early counts will be indicative only, as many more flowers are produced and set than the tree can bring to maturity. Many of the smaller fruit will be shed also, but the mortality rate rapidly decreases with size of fruit, and by taking

observations it is possible to determine a 'critical point' or size of fruit beyond which it can be confidently expected to reach maturity. Near this point it may also be possible to establish other 'critical points' at fractional levels of expectation, as for example, the even chance that the young fruit will reach maturity. The inter-fruit, inter-tree and seasonal variances are, however, large, and it is by no means certain that the very considerable mass of observations and statistical analysis required to set up any refinement on the one 'critical point', will lead to the discovery of functions with standard errors low enough to be of any practical use in forecasting.

The observations made will vary with the type of crop. Most of the techniques described in this paper refer to such crops as cocoa or coconuts.

Initially, the only recorded yield per acre may be from Government experiment stations and two points are worth noting. First, the levels of yield and crop characteristics are not likely to be representative of the typical peasant holding. Second, yield per acre of a marked plot is generally higher than that of the whole field or farm, particularly where planting is not regular, but random. One tree on the edge may take in many times the average root room and there may be patches within the field sterilized, as far as crop is concerned, by rocks, fallen trees and the like.

ACREAGE

The ideal would be a complete survey, kept up to date year by year by recording the new plantings, young crop coming into bearing and crop going out of cultivation. The useful information of each unit of area would cover natural conditions such as soil, drainage, aspect, slope, elevation, water table movement and liability to drought or flood, shade trees and shelter from wind, latitude and meteorological data. It would also include characteristics of the crop such as the distribution of types, tree sizes per acre, age, general health, cultural operations, presence of pests and diseases and plant sanitation measures adopted. It is, however, only an ideal, as changes in conditions of separate area units, year by year, would necessitate a complete resurvey each year. This is hardly conceivable with large capitalist plantations and impossible with peasant plantations.

Much useful information for forecasting can be built up. In the first place there may be export figures from several ports, on-loading tonnages at railway stations, quantities transported by canoe or boat or crossing river ferries, or perhaps passing through up-country markets or produce grading stations. A preliminary distribution map can be built up from these data giving very approximate acreage of mature cultivation by using a dot to represent some convenient fixed tonnage. This map may then be continuously improved as further indirect data become available, or are provided as a result of an organized survey.

The cost in time and money of a comprehensive survey is considerable. With permanent crops it can fortunately be made gradually by having a five or ten year plan, and covering one area each year by a survey team. By multi-stage sampling within the areas already surveyed and simple recording done by volunteers or staff who are engaged on other work in the area, it should be possible to record general trends and changes.

An alternative method is to make a quick sample survey of the whole

area. This can be done provided *linear* observations only are made. Having decided on the form of traverse, transect or bush path survey, the characteristics of the crop may be recorded against a suitable linear unit, the observer simply recording his paced distances, at each change of cultivation. The linear observations are translated or ' calibrated ' into area units by making a complete ground survey of a few key villages and computing conversion factors or functions. Even if the final total area is not highly accurate, the distribution of acreages, geographically and by crop characteristics will be satisfactory and suitable as a forecasting framework. The global acreage figure can be tested and revised as total information gradually builds up.

The conversion equation may be somewhat complex and will depend on the ' pattern ' of farm distribution. In the normal village settlement, farms will be cultivated near the village and the linear percentage of cultivation will fall off with distance from the village. On the other hand, the area of each successive ring of unit width increases with the distance from the centre of the annulus, so that each linear unit of cultivation represents a greater area as distance from the centre increases, provided the distribution is roughly random. No single formula can be laid down, but a combination of simple regression analysis and trial and error should produce a working formula. The type of formula will be dictated by the farm distribution ' pattern ', and its production may not be within the scope of the agricultural officer unless he has a flair for statistics or can enlist the assistance of a trained statistician. It should be possible to produce a formula which is accurate to within the limits imposed by the actual physical errors in making observations in peasant cultivation. For estimation purposes the distributions provided as a result of this type of reconnaissance survey will probably be as accurate as those provided by a complete ground survey taking perhaps five times as long and costing fifty times as much.

COLLECTING INFORMATION

Having established the general characteristics of growth and distribution of acreage, the collection of data specifically for crop forecasts and estimates can be planned. This will fall into four main groups : (*a*) crop reporters' statements, (*b*) meteorological data, (*c*) objective observations on the growing crop, and (*d*) statistical analysis of other data and time series.

Crop Reporters' Statements

The requirements for satisfactory statements made by reporters are (1) division of the whole area of cultivation into natural divisions, ignoring artificial political boundaries, (2) the availability of information to the reporter, and (3) continuity of residence of reporters in districts small enough for them to acquire personal knowledge of the cultivation and give sound judgement of their districts. The report form should be designed to record concise estimates, compared with previous season's results, and subjective judgments by the reporter of all necessary aspects of the crop. The records should be in a form which allows rapid analysis by the forecaster in headquarters.

Meteorological Data

That both weather and crop distribution are seasonal and therefore correlated is obvious. The complexity of such correlations and the fact that the variance in the yield of a single plot is only partly due to meteorological factors, precludes the establishment of any simple correlations or regression equations. On the whole and in spite of a very great deal of statistical analysis, the attempts to establish these production functions have not been very successful.

Simple graphical methods such as graphs using simple or logarithmic scales, scatter diagrams or histograms are probably as useful to the practical forecaster as the most intricate statistical analysis. Graphical methods should, in any case, be used first, and the permanent display of the diagrams on the walls of the forecaster's room is a most valuable adjunct. It is doubtful whether crop-weather data analysis will ever, alone, provide forecasts any closer than those of an experienced observer using empirical weather lore. The number of meteorological factors is larger than can be ordinarily handled in statistical analysis where the main aim is speed of result. The trained human mind acts as its own electronic computor and subconsciously handles many complex factors, its efficiency being expressed in success, whether in business, economics or crop forecasting. Complexity arises mainly because of interaction between weather factors and other factors. High effective rainfall at certain times and distributed in a particular manner may increase yields in some fields but depress yields in other low lying, poorly drained fields. The rainfall factor itself is difficult to express as the same amount of rain falling in half an hour may produce the opposite effect of the same amount spread over several hours. Simple daily records of rainfall such as those used by geographers to compile rainfall maps are of limited value in forecasting. The problem should, however, be continuously explored. Useful general characteristics may be found. Alternate year cropping is a common feature and weather *during* the growing period has a marked effect on outturn.

Objective Observations on the Growing Crop

By investigation of the growth curve, as described above, it is possible to forecast, with accuracy, the yield of a plot, by observations and measurements during the growing period. This fact can be made use of in a system of ' observation plots,' distributed throughout the growing areas. Their representativeness and so their efficiency in providing useful data for forecasting will depend on their numbers and on their distribution by age, soil type, *etc.* Observations may be eye estimates of fruit numbers, with some key plots recorded at harvest, for calibration purposes. The time taken to record individual tree crop counts on one-tenth acre plots, with time taken in travelling, precludes any large number of plots being recorded by one observer. Here a photographic method may be useful. By taking colour photographs from fixed points in the farms, the examination at headquarters of the transparencies through an enlarging-viewer will give counts of the ' seen ' crop, which will themselves be functions of the actual crop. The same total expenditure by this method might provide many times the data which would be obtained by direct visual methods.

Observation plots, for visual eye estimation, can conveniently be of one-tenth of an acre in size. A plot in the shape of an equilateral triangle of 100 ft. side is approximately of this size and is easily set out in farms with irregular planting. Without surveying instruments it is not easy to set out a rectangular plot accurately. A triangular plot can, however, be set out by putting in two pegs 100 ft. apart, and then stretching a 200 ft. rope from its centre point, with its ends fastened to the two pegs. A spot plan should be made showing positions of the trees and the shade trees, with the necessary characteristics recorded, together with the description of the plot itself.

For convenience plots must be accessible and this precludes any random selection, where the road system is not highly developed. Road or rail-side plots are not suitable as they are atypical. Another serious limitation on selection is the reluctance of some farmers to allow a plot on their farms to be recorded and the tendency for the best farmers to be the most co-operative, thus introducing bias. The whole matter of selection is one of compromise, and can only be dealt with by the judgement of the forecaster, the representativeness and the usefulness of the sample being gradually improved year by year. Some plots will be lost, and time-series based an any number of plots will be difficult to maintain. It may be necessary to abandon the attempt to use one permanent series of plots, and to make comparisons by using identical samples of plots for adjacent years only.

In the early stages monthly, or even fortnightly, recordings may be advisable, but as knowledge is gained, it is probable that observations made at one fixed date before the season begins and at one other date for progress reports, will be sufficient for forecasting purposes. Unnecessarily frequent recording merely provides a mass of data which it is impossible to handle and obscures the mental picture of the person using the data.

The 'score card' technique may also be found useful. Observation will show that correlation exists between soil and other natural conditions, and the yield. There are also parallel factors in a high-yielding tree : these may be leaf size and colour, denseness of canopy, absence of pests and diseases. Other factors have a bearing on the yield per acre, such as tree size, planting distance and age of tree. By making a list of these factors and giving a score of, say, one to five, against each, the aggregate score gives an assessment of the yield capacity. A well known example of this method is that used in the photographic exposure calculation table based on latitude, time of year, time, general light conditions, and subject. The production of a score card is mainly one of judgement based on knowledge and experience of the factors, and of trial and error.

Recordings of this nature, made on a journey through the growing areas, are a safer guide than memory of what the farms looked like last year. I recall one case in the Gold Coast where the score card results forecast the actual yields from experimental plots in peasant farms with uncanny accuracy, and I consider that more use of this method could profitably be made.

STATISTICAL INVESTIGATIONS

Secular Trends

The size of the crop depends, not only on the seasonal variation, but on factors causing secular trends. Where the acreage is increasing, production

will rise but the relationship between acreage and production is complex. The yield varies throughout the economic life of the tree, and the nature of these variations must be determined. An example of a normal biological yield curve is as shown in *Figure 3*.

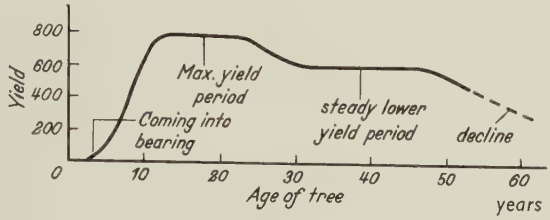

Figure 3. Biological yield curve

The curve may be established by reference to long term yield data where such records are available, or by the survey method which consists in taking present yield records on plots of known age over as long an age range as possible. The information is again indicative rather than exact as the shape of the curve varies with conditions and may also be affected by a space factor. The first plantings of a crop frequently come into bearing earlier than the mass plantings made when a crop has already been established over a wide area and in a concentrated pattern. The reduced concentration of insect pollinators, absence of alternative forest host plants or insect pests and changes in the micro-climate due to reduction of forest cover tend to affect the shape of the curve.

The next process is to graph the existing time series—exports, marketed tonnages, *etc*—to determine the general production trend. From the two curves it is then possible by interpolation to construct approximate curves showing the acreage planted up each year. Equally important is the area going out of bearing and it is therefore necessary in crop reports to include data of new planting and of areas going out of cultivation. In the case of both the biological yield curve and the production secular trend, there is little to be gained by attempting to calculate regressions as the curves are not definable by any simple equations. The drawing of smooth curves through these points, plotted on a large size sheet of linear or logarithmic graph paper, can be checked by reading off the differences between the actual values and curve values, and choosing the curve which gives the least value of the aggregate of the squares of the differences (method of least squares). Separate curves may with advantage be constructed for each of the natural regions.

Crop-weather Correlations

Total annual production and total annual rainfall seldom show significant correlation. An average deviation of 25 per cent from the mean for a short period of years and as high as 50 per cent from the mean for a long period of years is not uncommon for a single field, the explanation being found in the shape of the biological yield curve. On the other hand there is a high correlation between the distribution of rainfall over the year and the distribution of crop over the year. If average distributions are computed

from several years' records, the two series can be plotted and the graphs superimposed, or correlation coefficients can be worked out for varying periods of lag between rainfall and yield. By either method the number of weeks between rainfall and ripe crop, which gives the nearest fit, can be found and this will suggest the first line of investigation.

Gradually it will be possible to establish correlation with effective rainfall (*i.e.* that portion of the total precipitation which enters the ground and is not lost by surface run-off) at certain critical periods during the year. The rainfall may of course be nil, and the length of the dry period be the critical factor in crop failure. Alternatively high rainfall, particularly in heavy concentrated falls, at time of flowering or fruit setting, may reduce the crop, whereas well distributed and frequent light rains during the growing period may be the dominant factor in yield. These correlations can only be found by trial and error, experience and time.

Production Characteristics

By examination of the yield data, particularly when graphs and diagrams are used, characteristics peculiar to the crop may be spotted. No generalizations can be given. Examples of this are alternate year cropping, a large 'minor' crop following a short season 'major' crop, the tendency of the distribution of the crop over the year to vary with age of tree, latitude, and other conditions.

Economic Factors

Even where forecasting is confined to biological production, economic factors cannot be ignored. Prices, and therefore incomes, are liable to affect the expenditure on such items as cultural operations and fertilizers. In Trinidad cocoa I found that what at first appeared to be cyclical trends in yield per acre, were closely correlated with the trade cycle. On the other hand, with family farms employing no paid labour, low prices may in some circumstances lead to increased activity with the intention of increasing yields and maintaining income. The backward sloping supply curve is not a simple attribute of particular types of farmers, but a complex of price level, wages, and many other factors.

One factor to be remembered is that the more remote and inaccessible the farm, the greater is the price differential, and prices may fall to a point where the differential is greater than the market price, so that the crop will not pay to harvest if any money costs are involved.

The lag between ripening and harvest and between harvest and marketing may be directly affected by weather conditions, and also by the farmers' assessment of market prospects. Marketing and export forecasts are no less speculative than production forecasts.

THE REPORTING SERVICE AND THE CROP REPORT

A full crop report would cover forecasts, estimates and progress reports on all aspects of the growing crop and the marketed product. The essence of a good forecasting service is accuracy and speed. As information becomes available it should be assembled, collated, analysed, and the final data and forecasts presented in a systematic manner. Successful organization depends to a large extent on correctly designed forms for

reports and analysis, with exact instructions and flow sheets covering the complete office process between any one report or fact being received, and the final information being presented in the published report. Statistical tables, maps, diagrams and graphs which are kept up to date by the continuous addition of the latest information should also form part of an automatic process. Where tables or diagrams are included in the issued report, there is advantage in using a spirit (as opposed to stencil) duplicator as the master copy can be filed, and the latest information be added in the desired colour, and copies run off immediately.

The important summary tables and graphical information should be mounted round the walls, and on a scale large enough to use from one position, where this is possible. The eye can then move from one to the other and a composite picture be built up in the mind, which it is impossible to get from turning over sheets in a file.

Statistical data from observation plots may be summarized for districts and for characteristics by grouping plots of the same age, planting distance, *etc.* When knowledge obtained by survey of the whole cultivation is sufficient to enable acreage distributions of different characteristics to be computed, these may be used as weights in calculating means from the plot data. The plot data will be used by the district reporter in forming his forecasts, and too great a reliance on a few plots is a frequent weakness in the reports of inexperienced reporters. It would in some cases be preferable to have one part of the report based on general observations, prepared before figures from plots were studied.

Whether the whole information is fed into one central office only or dealt with also in the main natural regions separately is a matter of organization. Much information can be gained from produce buyers and farmers, and local committees having access to all the local information under the chairmanship of the crop reporter can provide district forecasts. The aggregate of these district forecasts is a valuable addition to the forecast prepared in headquarters, but it is necessary to take note of bias in the opinions of interested persons. The buying firms will have a great deal of information from their brokers and buyers.

The methods outlined in this paper give different approaches to the problem of producing a forecast of the forthcoming crop. Each method, crop reporters' forecasts, computation from observations taken in plots, statistical investigation, *etc.*, should first be used separately and the forecast based on that method worked out. Then the forecaster will make his own assessment and produce an official forecast. The advantage of keeping forecasts provided by different methods separately, is that the subsequent estimate of the production will be available for comparison and each individual method can be steadily refined.

(*Received August 1954*)

APPENDIX

TERMS USED

Estimates.—Quantitative statements prepared at harvest or soon afterwards. ' Preliminary estimates ' issued as early as possible, revised as information becomes available and is analysed, until a ' final estimate ' can be prepared.

Forecasts.—A prediction or estimate made during the growing period. Will be revised and improved as additional observations and reports become available.

Crop outturn.—Should refer, strictly, to the actual biological production by nature, but is loosely used also to denote the (*a*) quantity harvested by farmers, (*b*) quantity brought to market by farmers, (*c*) quantity exported or handled by the central marketing system.

There will be ' wastage ' at all stages.

The crop should be exactly defined, as for example, wet weight or dry weight, in shell or decorticated.

Production.—Term used to denote different things. The quantity required for seed for the next crop may be deducted from the ' gross ' to give the ' net ' production.

In market reports, production often refers to exports during a particular twelve months' period, which may be the calendar year, accounting year, or natural crop year, ignoring ' carry-over '.

Shipping weights in customs statistics may be nominal weights and exclude the excess quantity contained in the bags against loss-in-weight during shipment, of up to 2 per cent in some cases.

Tons may be ' long ' (U.K. 2240 lb.), ' short ' (U.S. 2000 lb.), or ' metric ' (2200 lb.).

Carry-over.—The quantity of one season's crop, still in a particular stage of the producer-to-consumer chain, when the current season's crop comes in, *e.g.* quantity as stocks in exporters' hands when buying of new crop begins.

Outlook charts and statements.—Give the forecasts and estimates of the crop at all stages, and may refer to production trends several seasons ahead, and also to market trends.

Postscript

The author would be grateful to have any material on forecasting and estimating, with description of methods, copies of forms used and results, *etc.* This would be very useful for oversea courses and for the information of agricultural officers and others, who visit Oxford. Please address communications to *W. H. Beckett, Agricultural Economics Research Institute, Parks Road, Oxford, U.K.*, or call at the Institute when in Oxford.

Enclosure and Land Settlement, and the Evolution of West African Agriculture

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The erudite article by D. C. Igwe on 'The Need for Enclosure and Land Resettlement in Nigerian Agriculture' in *Tropical Agriculture*, Vol. 31 (No. 1), January 1954, was most interesting and even encouraging in that it shows the Nigerian intelligentsia have a lively interest in the future of their country's agriculture. On the other hand, it is to be doubted if Mr. Igwe's approach can be considered likely to be fruitful, inasmuch as he leans heavily on a presumed analogy between the evolution of English agriculture and the beginnings of an enclosure movement in Nigeria. It is not so much the system of land tenure which has made English agriculture what it is today, but rather a peculiar concatenation of circumstances—ecological (soils and climate), economic, social, and even psychological, which has had as its end-point the present system of English land tenure—a system, which in a West African context is not necessarily good.

On the road from a community of bondsmen working strips in unenclosed 'open fields' for cultivated crops, and utilizing 'common' waste and meadow land for cattle and pig keeping, to a mixture of rent-paying peasants, yeomen, and capitalist farmers working enclosed fields, and finally to the present system of large and small farms, two thirds of which are rented, and one half operated by wage labour, unpredictable historical events, themselves undirected, have conditioned the course of agricultural development in Britain.

The Black Death (1348–1349) decimated wholesale the English peasant population, bringing in wage labour and accelerating the change 'from status to contract'. The Peasants' Revolt in 1381 alarmed the feudal rulers as to the dangers of a free peasantry and the advantages of a landless proletariat. The rise of industrial as well as agricultural capitalism encouraged what social direction or economic pressure could be applied to the creation of large farms, operated by paid labour, and the gradual elimination equally of the individual craftsman working for himself, or in a small group of his fellows, and the free peasant working his few acres with the help of his family. Finally, the activities of innovators or 'improvers' such as 'Turnip Townshend' and Coke of Norfolk had a great influence in making agricultural production per acre more efficient. Not all of these men were farmers themselves, but they were a useful yeast, even if all their ideas were not sound.

The elimination of the peasant made a more efficient but not a more stable agricultural pattern of production: great strides in technology involved at times great social wastage: 'the greatest single event of the "seventies"

was the sudden collapse of English agriculture . . . the cause was the development of the American prairies as grain land within reach of the English market. There was no longer in England as there was in other European countries a peasantry to plead for protection and so, at the end of Victoria's reign when the pinch of foreign competition came at last, the urban electorate would listen to no proposal to save British agriculture from ruin '. (G. M. TREVELYAN, *English Social History*).

Any sudden change to individual ownership would lead to unending lawsuits, owing to the existing confusion, as to land rights, at least if the Nigerian situation is anything like that in the Gold Coast.

' Were it not for long service in West Africa it would appear to me to be not only incredible but impossible that such divergence of opinion could exist upon such a fundamental point of law as to who are the persons entitled to an estate in that land in the circumstances already described. It is equally clear that despite the passage of many years and many judges, there is very little authority whereby one can pronounce upon this matter with any degree of certainty.' (J. N. MATSON, quoting a judicial pronouncement in *The Modern Law Review*, Vol. 16, No. 4, October 1953).

There is a vast difference between historical change and change by administrative or legal fiat. However, even if in West Africa a reorganization of farming were acceptable to the people, and involved no social strain (though it is difficult to see how this could be avoided in creating a landless proletariat by expropriation of existing land rights), one must ask what improved technical methods could be brought to bear. The British farmer can and does purchase fertilizers in huge quantities, and has also added large increments of fertility to the soil by the use of imported feeding stuffs. Good communications and huge city populations within easy reach made it economically worth while to engage in ' high farming '. He was always aided by extraneous power (I mean apart from human muscle); at first oxen; then horses; then tractors, and a wealth of cheap and efficient farm machines, on the land and on the farm. Over a century's scientific research in all aspects of agriculture is available to him.

By contrast, West African farmers have still to depend on the cutlass and the hoe, and in few cases will the value of the crop justify expenditure on fertilizers. Over large areas cattle cannot be kept for draught or for manure, and the use of tractors is uneconomic or not feasible by reason of the lack of trained operators. There is a great lack of scientific knowledge of tropical soils and soil management. Has the problem of shifting cultivation been solved anywhere, without cheap sources of extraneous fertilizers being available ? I think the answer must be ' no '. The peasant farmer has long since learnt that time and ' nature ' will restore ' fertility ' (by this is meant recovery in soil structure as well as in nutrient content) without effort and without imports of fertility from external sources. This is an economic ' application of scarce means to alternative uses ', the scarce means being power, and fertilizers.

This system is also soil conservation in its true sense, and the western communities who mine mineral nutrients from not inexhaustible sources in the earth, or who mine coal to make energy to fix nitrogen at great expense, and who, later in the cycle, take great trouble to get rid of sewage to the

sea rather than the land, are the greatest wasters of fertility. The chemist cannot make phosphate or potash, we can only move these compounds from the rock, to the soil, to the plant, to the animal body, and then either back to the soil, or to the sea.

The West African peasant, then, is farming as best he can with his limited resources. And judging by the trials to date of the large-scale organizations (see any C.D.C. Annual Report) we have probably still much to learn before we can teach him a better permanent system.

Having seen that cheap power and cheap fertilizers, or very much dearer food to enable farmers to purchase these aids from cash income, are the only alternatives to ' shifting cultivation ' at present, how much of the case for enclosure in individual farms of the land now farmed on the old system remains ? Apart from the maintenance of soil fertility, the other major technological problem in West Africa (and perhaps throughout the tropics) is the prevention of soil erosion. *Prima facie*, it seems unlikely that individualist farmers, farming unconnected units, would be the ideal system to facilitate the construction of soil erosion works or adherence to conservation regulations. It seems likely that this system would on the contrary favour exploitation of the soil and its degradation and erosion, the more especially as the input of capital in such ' indirect ' improvements as might assist a neighbour as much or even more than the farmer himself, would have little appeal.

It seems likely that the road to co-operative farming, though it bristles with obstacles and difficulties, both technical and social, is the more promising one for West Africa to follow. It would allow of the following desiderata being incorporated in the working of the new units:

Economic use of tractors, cultivating and processing machinery.

Bulk sales and bulk purchases.

Economic use of scientific advice and business management.

Soil conservation works and practices on a large scale.

Utilization and intensification of the social cohesion existing in tribal organization, and providing a milieu in which leadership can develop, under shelter.

Mr. Igwe contemplates, apparently with equanimity, the creation of an agricultural bureaucracy to order the process of enclosure. The right to enclose would be ' safeguarded ' by making it contingent upon ' evidence of no tendency to agricultural landlordism or sub-infeudation ; evidence of ability to comply with good husbandry legislation '. *Quis custodiet ipsos custodes* ?

However, Mr. Igwe is not alone in his view. G. S. Beckett, for instance (writing in ' The New Commonwealth ', issue of 18 January 1954), says, ' . . . in short my own view is that we shall shortly have to consider licensing African farmers and only licensing those who submit to a minimum standard of agricultural production '.

To my mind such an approach is a confession of failure—failure to get close enough to the African farmer to know what his social and technical problems are, and what difficulties he will have to surmount in making, or accepting, changes in his traditional methods and system of farming.

Extension services are weak. Not only are the European extension officers 'thin on the ground'; the agricultural officer, if he is English, has been brought up in the tradition of the large individually-owned farm, operated by men who are of his own or of superior social standing, and who 'speak the same language' both literally and technically. He is further handicapped by the lack of training in extension methods suitable to a peasantry, and has often a concomitant lack of sympathy with or interest in peasant agriculture. The phenomenon of 'perceptual defence' operates here, and the extension problem is very often not so much ignored as unnoticed.

It seems unlikely, given a continuance of the educated African's reluctance to work with his hands, and his sense of superiority to those who do, that he will fill this gap. It will rather be filled by persons—European or African—who like to work with people, and whose technical training is wholly practical, in soil and plant science, in animal husbandry, in farm management and marketing, in erosion control on the farm scale, even in house building and road making.

By the time these gaps in agricultural extension are filled, it seems likely that faith will have dwindled in the large overseas organizations highly capitalized by the British taxpayer. It should then be possible to secure capital for modest schemes, frankly experimental to start with, to form a working partnership between science, capital, and willing groups of African farmers, who will be expected and encouraged to contribute their own ideas, and eventually manage their new units of organization. I would choose to call these, after the English model, Land Settlement Associations.

Addendum on Group Farming. Since the foregoing was written the following reference to group farming in East Africa has come to my attention:

'Frequent references have been made in various connections earlier in this report to group farming in several areas. No development in recent years has shown greater promise not only in relation to the simple efficiency of production, but to the better utilization and better farming of land. Although still in its infancy the movement is strong and appears to rise from the fact that some form of communal work in crop production is traditional and inherent in the social framework of many tribes. . . . Apart from the social and practical advantages to be gained from this system it may well be related to concepts of land ownership being vested in the tribe rather than in the individual, but whatever the reason may be, it is found to some extent in all tribes even among those with a highly individualistic outlook.' From Annual Report 1952 of the Department of Agriculture, Uganda Protectorate.

(*Received April 1954*)

Anthracnose: A Serious Disease of Tobacco Nurseries in Northern Rhodesia caused by Colletotrichum tabacum *Böning*

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Early in 1953 my attention was drawn to a leaf and stem blight in tobacco nurseries in the Choma–Kalomo area of Northern Rhodesia which was causing serious damage to seedlings. Widespread enquiries of growers in this area revealed that the disease had appeared as far back as 1949 but was assumed to be an aggravated form of damping-off (due to *Pythium* and *Rhizoctonia* spp.) and therefore gave no undue cause for alarm. However, the disease continued to spread further in each subsequent season, frequently reaching epidemic proportions in the nursery beds. Up to and including the 1952–53 season no reports had been received of field infection and the disease normally declined and disappeared after transplanting. During the 1953–54 season, however, several cases of leaf-spotting and stem canker on field plants were brought to light due to the same fungus. Both Virginia and Turkish tobacco types are susceptible to the disease.

SYMPTOMS OF THE DISEASE

The first signs of infection appear on the seedling leaves close to the soil and take the form of dull green water-soaked spots 2–3 mm in diameter. These spots later enlarge, becoming pale brown in colour and are frequently delimited by a darker brown zone adjoining the healthy tissues of the leaf. Spots seldom exceed 10 mm diameter but coalescence between neighbouring lesions rapidly causes the death of these leaves. If the attack commences when the seedlings are quite small (at the 2-3 leaf stage) patches of the beds may be killed off simulating the effects of damping-off as has already been mentioned. The above symptoms I have denoted as the 'primary phase' of infection (*Figure 1*). This type of symptom is considered to result from infection from the soil. What I have termed the 'secondary phase' of infection might almost be mistaken for another disease entirely (*Figure 2*). It is characterized by the production of thousands of pin-point spots with light-brown to white centres and usually occurs on the larger seedlings. This type of spotting appears to be due to profuse sporulation of the fungus on the primary lesions, the spores subsequently setting up the numerous individual infections. The intensity of this type of spotting is such that unequal growth of the leaves results, causing puckering and distortion, and they become ragged and torn.

Attacks also occur on the young stems, petioles and midribs and are characterized by deep dark-brown longitudinal lesions. Snapping of leaf midribs at the points of infection frequently results, the leaves then hanging downwards.

Figure 1. Disease beginning on young seedlings. 'Primary phase'

Figure 2. 'Pin-point' spotting on older leaves. 'Secondary phase'

Leaf-spotting on field plants is less intense, there usually being only a few discrete, light-brown to white lesions delimited by a darker zone. The attack on the stems is, however, unusually severe. Deep broad cracks and bands appear at soil level, these girdle the stems and kill the transplants. The occurrence of the disease in the field after setting-out has not been widespread and seems to be associated with damp patches of soil. Up to the time of writing no cases of flower or seed capsule infection have been reported.

IDENTITY OF THE PATHOGEN

In every case, examination of lesions disclosed numerous acervuli with cylindrical, guttulate spores borne between stout dark-brown setae. The fungus was provisionally assigned to the genus *Colletotrichum* and material sent to the Commonwealth Mycological Institute for further identification. Diagnosis was later made as *Colletotrichum tabacum* Böning.

At the time the first examination of lesions was made, no facilities existed for isolating the fungus. Isolations were, however, made the following season and the fungus obtained in pure culture. Pathogenicity was proved by spraying tobacco seedlings with a spore suspension of the fungus and subsequent re-isolation of *C. tabacum* from the lesions.

Böning[1,2] first described *Colletotrichum tabacum* in 1929 but did not give it a name till 1932.

Böning's diagnosis gives the conidial and setae measurements as follows :

Conidia = $15-22 \times 4-5\ \mu$
Setae = $60-90\ \mu$

Measurements of the fungus in Northern Rhodesia are :

Host: Conidia = $8-18\ (13{\cdot}6) \times 2-6\ (3{\cdot}5)\ \mu$
Setae = $52-176\ (111)\ \mu$

Culture on cornmeal agar :

Conidia = $8-14\ (11{\cdot}8) \times 2-4\ (3{\cdot}3)\ \mu$
Setae = $42-192\ (94{\cdot}5)\ \mu$

Two other species of *Colletotrichum* are recorded from tobacco, namely *C. nicotianae* Averna Sacca from Brazil and Indo-China, and *C. destructivum* O'Gara, the latter primarily a parasite of clovers and lucerne in the U.S.A. Both of these species are reported as causing damage similar to that of *C. tabacum.*

SOURCES OF INFECTION

Böning reports that tobacco anthracnose in Germany is seed-borne. This does not appear to be the case in Northern Rhodesia. Repeated attempts to isolate *C. tabacum* from seed taken from plants raised from infected seedlings have given negative results. This is in accordance with the failure, to date, to observe infection of flowers or seed capsules in the field. Furthermore, many growers annually purchase seed from places outside the territory where the disease has not been recorded. This does not preclude the possibility that the disease was introduced into the territory on seed in the first instance. The sudden occurrence of the disease in 1949 would lend support to this possibility.

That the disease can be carried in the soil in Northern Rhodesia has been confirmed. Plating of serial dilutions of soil on anti-bacterial media, from previously infected beds failed to reveal *C. tabacum* probably owing to competition from more vigorous fungi. However, seedlings raised aseptically in petri-dishes sprayed with soil suspensions developed lesions within four weeks, while ' controls ' sprayed with sterile water remained free of infection.

Outbreaks of anthracnose on farms not having previously recorded the disease strongly suggest that spatial spread in the area in question is by wind. That sporulation is profuse has been mentioned previously.

ENVIRONMENTAL FACTORS

The disease has frequently been observed to start in retarded portions of beds where the seedlings are yellow. These are generally waterlogged patches or areas of high soil pH. It is of interest to note here that in culture *C. tabacum* favours an alkaline medium, growing well at as high pH as 9, and sporulating profusely. pH of 4 or less considerably checked growth. This may explain the initial outbreaks on alkaline soils.

Böning recommends that the beds be well ventilated and that the sowing rate be reduced to help achieve this. Reduction of the seeding rate and removal of the cloth covers on the beds as soon as possible failed to check the disease in Northern Rhodesia, however. Tobacco beds normally receive at least three waterings per day and are prepared at the hottest period of the year—September–October, and it is doubtful whether humidity could be sufficiently reduced by lowering the seeding rate in order to effect control of anthracnose. There is some evidence to suggest, however, that low-lying sites are predisposed to infection as compared with those on higher ground enjoying a better air circulation.

CONTROL MEASURES

In Bavaria, Böning found that seed disinfectants, particularly silver nitrate, followed by spraying of seedlings regularly with Bordeaux mixture or other copper fungicides were effective in controlling anthracnose[2].

An intensive campaign among affected tobacco growers to treat seed with silver nitrate and spray nursery beds every five days with 4:4:50 Bordeaux mixture was initiated in Northern Rhodesia in September 1953. While the early sowings remained relatively free of the disease, by early November there were large-scale outbreaks of ' primary ' infection over several farms. Spraying was continued throughout the remainder of the season but cannot be claimed to have been a success. It was observed, however, that there was little tendency for the ' secondary phase ' of infection to develop and it was concluded that Bordeaux mixture had checked the sporulation of the fungus. This was later confirmed by laboratory examination of sprayed and unsprayed lesions.

It is now apparent that some form of soil disinfection in addition to protective spraying will be necessary to bring the disease under control. Burning of the beds with brushwood, the normal method of soil sterilization, has failed to check outbreaks of anthracnose and has the undesirable effect of raising the soil pH. Work is now proceeding on the testing of various

chemicals for soil treatment and the screening of fungicides for use as protective sprays.

ACKNOWLEDGEMENT

This paper is published by kind permission of the Director of Agriculture, Northern Rhodesia.

SUMMARY

Anthracnose, a serious leaf and stem blight of tobacco seedlings caused by *Colletotrichum tabacum* Böning, is described. In contrast to the disease as it occurs in Germany, in Northern Rhodesia it is apparently soil and wind-borne rather than seed-borne. Reduction of the seeding rate, seed treatment and spraying the seedlings frequently with Bordeaux mixture have failed to check the disease effectively.

(*Received March 1954*)

REFERENCES

[1]Böning, K. *Prakt. Bl. PflBau* **7** 1 (1929) 36–39; *Abs. R.A.M.* **8** (1929) 680
[2]— *Prakt. Bl. PflBau* **10** 3–4–5 (1932) 89–106; *Abs. R.A.M.* **11** (1932) 753

Control of Witches' Broom Disease of Cacao in Trinidad

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Witches' broom disease of cacao (*Marasmius perniciosus* Stahel) is one of the factors limiting production in parts of the western hemisphere. Control by highly resistant trees is not possible at present and my purpose here is to discuss control by the removal of diseased material. Satisfactory control is possible by this method and it could become increasingly efficient as a change to more intensive cultivation takes place.

The last discussion of control measures was made by BAKER and CROWDY (1944). Their recommendations are still insufficiently applied. The spread of the disease in Trinidad between 1928 and 1939 coincided with economic depression; this, together with inadequate knowledge, prevented effective control. Prices are now good and the necessary knowledge is accessible; furthermore, varieties with a lower susceptibility to the disease and higher yielding than the average seedling progeny are available. Experience at the British West Indies cacao research scheme's field experiment station at River Estate (Trinidad), where incidence of the disease probably reached maximum intensity ten years ago (BAKER and DALE, 1944*a*), has shown clearly that the control measures laid down in 1944, can be effective.

TIME AND FREQUENCY OF REMOVAL

Removal and destruction of diseased material (*i.e.* the witches' brooms) to prevent the formation of spores was first recommended by STAHEL (1915) in Surinam. Changes in the method since it was first put into practice concern the time and frequency of removal; doubt has also been expressed as to whether destruction, after removal from the trees, is necessary. Stahel recommended a removal once every three or four weeks. STELL (1932) in Trinidad, suggested four times each year, special attention being paid at two periods—April and October. BAKER and CROWDY (1943) concluded that two removals a year at the times Stell proposed for special attention were sufficient. It will be convenient to summarize the facts on which Baker and Crowdy based their suggestions.

Infection of the young flush is followed by an incubation period of about six weeks (extremes $3\frac{1}{2}$–14 weeks) before the first symptoms appear. The broom becomes fully developed some two weeks later. Incubation varies with flushing behaviour and the complete symptom picture usually appears with the flush following the one in which infection occurred. Brooms remain green for three to six weeks, after which the host tissue dies. Then follows a variable dormant period before the sporophores appear—a mean of 22 weeks (extremes 10–66 weeks). A minimum time of 13 weeks must therefore

elapse before a green broom can fructify and cause new infections. Theoretically then, as stated by Stell, control may be achieved if brooms are removed once every three or four months.

However, the dry season inhibits a stage of the disease in that sporophore growth, from February to May, is insignificant. The onset of the wet season in June stimulates fructification and the sporophore index (the number of sporophores per week produced by a random sample of 100 brooms of all kinds) increases to a maximum in December or January, at the end of the wet season. The appearance of brooms also follows a cycle. Their numbers are low from April to July, but increase after the start of the rains and reach a maximum in February or March. A significant positive correlation was found between the numbers of sporophores in one week and the numbers of developing green brooms five weeks later.

The best time for the first removal of brooms each year is late April. This is because broom production is at a minimum and because the large numbers of brooms which develop in the first three months of the year can be destroyed in one operation. After April, new brooms are not seen until about six weeks after the first rains, that is, in July. By November these new brooms may be sufficiently mature to produce sporophores; a second removal should therefore be carried out before this can happen, that is, in October. This removal is important because it enables any material missed in April to be dealt with and prevents fructification of brooms formed after that month. It ensures that all brooms developing subsequently will not mature sufficiently to sporulate until February at the earliest, that is, in the dry season when conditions are highly unfavourable for sporulation. It also minimizes infection of the pods, the main harvest of which is just beginning. Therefore the dry season enables two removals each year to be dispensed with, leaving only two to be carried out at specific times.

TRIALS IN CONTROL

Experiments to test the control procedure outlined above were laid down by THOROLD (1943*a*), who came to the conclusion that the method was ineffective under the conditions of the experiment. However, his apparent failure to demonstrate control might be due to one or more of three reasons:

(1) Removal was not sufficiently complete and therefore reinfection resulted from material left behind. Thorold's work had to be carried out on old cacao, since these were the only trees available, and BAKER and CROWDY (1944) have referred to the reasons why removal of brooms, even by skilled labour, was inefficient on trees of this kind. It had been suggested that brooms cut from the trees might be left lying beneath them because rapid decomposition prevented fructification; Thorold carried out this procedure. Sporophores have, in fact, been found at River Estate on brooms and on diseased pods left lying under the trees.

(2) Stimulation of axillary buds near the cut end might follow the removal of a broom and by thus increasing the number of infection points, the number of brooms might rise. BRITON-JONES and CHEESMAN (1931) maintained that removal of brooms increased bud development. Although some of the axillary buds do develop, on removal of a terminal fan-broom

for example, THOROLD (1943*a* and *b*) concluded that this did not result in a significant increase in the number of brooms. Naturally, any increase in the number of brooms in the treated areas due to bud stimulation and subsequent infection will tend to mask any decrease due to inoculum reduction brought about by broom removal. Although there are no data to support this possible effect of cutting out, the importance of careful pruning in preference to mere elimination of diseased material must be noted.

(3) Reinfection of the controlled areas from the contiguous uncontrolled areas may have occurred. It was shown at River Estate that infection in one field, measured by broom counts, could be caused by wind dispersal of basidiospores from a neighbouring field. There was a gradient of infection and the most serious spread was considered to be up to 100 metres (BAKER, CROWDY and THOROLD, 1941). It is possible, therefore, that in THOROLD's experiments reinfection of the treated areas occurred although he was unable to show this. Baker, Crowdy and Thorold's observations had been made on a uniform stand of young cacao where the data obtained could be expected to be accurate. Also it was apparent, before the recording began, that the drift of spores into the field was in one direction. By contrast the later, negative observations were made on tall, old trees in which accurate assessment was more difficult and under conditions in which it was not possible to predict the direction of spore drift.

DEVELOPMENT AND SPREAD

The behaviour of this disease suggests that spore movement both within and between fields has a direct bearing on control measures. Little is known about the spread of air-borne spores in a tree crop but there is evidence that pod and shoot infection differ independently of one another; each varying according to the source, distribution and number of basidiospores being dispersed. Records at Marper Estate, where the disease was first recorded in Trinidad, show that at first, infection spread most rapidly in the leaf canopy. The number of brooms recorded was high before any comparable rise in fruit infection took place. Observations at River Estate show the same tendency, that is, when the disease reaches an uninfected area, the peak of vegetative infection appears to occur before that of pod infection (BAKER and DALE, 1944*b*).

In the varietal trials at River Estate, in spite of careful removal of brooms, pod infection remains quite high (*Table 1*). Inoculum in these trials may be originating from three possible sources of diseased material: (1) Neighbouring fields; (2) Trees of the field itself; (3) Excised brooms left on the ground in the field itself.

(1) Originally, infection from neighbouring fields occurred (BAKER *et al*, 1941). Subsequently, in 1947 severely diseased old cacao fields nearby were removed, and from 1947 to 1949 all the surrounding heavily infected areas were cut out. It is considered, therefore, that from early 1950 there has been no significant amount of inoculum reaching the field from elsewhere since the nearest old infected trees are three-quarters of a mile away.

(2) Infection from trees in the same field was probable because broom removal in it was irregular until the end of 1949. Subsequently, regular cutting every April and October has been done and little development of sporophores on the trees has been seen. This source within the field may now have less importance.

(3) Infection from excised brooms thrown on the ground is thus possibly responsible for some of the pod loss. Early in the history of the disease in Trinidad it was found that brooms fructified on the ground and they have been observed to do so in this field. However, it still has to be demonstrated that their destruction results in a lowering of pod infection beyond that which would have resulted from leaving them to rot beneath the trees.

Table 1. Pod Infection on I.C.S. 1 in Field 7 at River Estate

Trial	1943	1944	1945	1946	1947	1948	1949	1950	1951	1952	1953	*Total trials*
1	10	10	13	6	6	4	13	10	18	—	—	11
2	6	14	12	7	6	10	17	12	21	—	—	12
3	6	14	7	4	7	6	10	10	16	—	—	11
4	—	15	5	2	5	4	8	6	9	13	7	7
6	—	—	—	3	4	7	6	13	17	25	16	13
Total years	8	12	10	5	6	6	11	10	15	21	10	10

Figures are the percentage of infected pods from 96 trees.

BAKER and DALE (1944*c*) noted that losses in this field, where efforts at control have always been made, were appreciably less than those (44 per cent) in an adjoining old field where control was not practised. Nevertheless, the table shows that, in spite of removal of brooms, these losses have remained fairly constant, although much lower than those which could have occurred in the absence of control. It also shows that the complete removal of surrounding heavily diseased fields (completed in the dry season of 1949) has not reduced pod infection; but that in the early years up to 1947, when the field was surrounded by reservoirs of inoculum, losses could be reduced appreciably by removal of brooms.

These observations are made from results in clonal cacao under better conditions for control than in many Trinidad fields. The yearly variation presumably depends on weather conditions and the heavy losses in 1951 coincided with an annual rainfall amounting to 110·72 in., the 21 year mean for the estate being 71·96 in.

SPORE DISPERSAL

Certain observations (1–5 below) on the development of the disease in the field require explanation.

(1) As infection spreads into a healthy area, brooms appear more rapidly at first than do diseased pods.

(2) Pod infection does not become serious until relatively large numbers of brooms have developed.

(3) Control of pod infection in a given field can be fairly successful even though the disease in neighbouring fields is uncontrolled.

(4) Infection does not decrease below a certain level in an area where the disease is well established under the present control regime.

(5) Spread of infection from field to field cannot be shown clearly by counts of infected pods.

If healthy susceptible cacao is being infected by air-borne basidiospores from a distant source, these spores first cause scattered infection in the upper parts of the leaf canopy. Relatively few penetrate to the flowers and fruit, which are borne only on the trunk and main branches. As the first brooms in the new area begin to produce sporophores, infection spreads increasingly amongst the branches—a result of spores originating nearby rather than from the original source of infection. As the number of spores builds up in the branches close by, infection spreads downwards to pods and cushions and losses become serious.

When no control is practised, the disease soon reaches maximum intensity, the trees become covered with brooms and pod infection reaches 70 per cent or more. Obviously the effect of inoculum coming from a distance is now much less important. If brooms are removed in the area but not from neighbouring fields, spore intensity will decrease and pod infection will remain low even though numbers of fan brooms may remain high. Thus removal of a distant source of infection is not necessary in order to reduce losses directly in the treated area. But it is desirable so as to reduce the tree damage and cost of repeated heavy cutting out of fan brooms in this area. Since pod infection is considered here to be due almost entirely to basidiospores arising close by, it is possible to explain why a distant source of spores has no effect on it, and why infection gradients will not be shown on the pods in sites becoming newly infected. The epidemiology of this disease agrees with that of other air-borne diseases in the overriding importance of dissemination over short distances (Gregory, 1945 and 1952 and Ingold, 1949). The fact that infection does not decrease below a certain level is a reflection of the impossibility of—in practice—removing all infectious material in an area where the disease has become well established.

SUMMARY

The control of witches' broom disease can be satisfactory in Trinidad—if brooms are removed every April and October—except on heavily diseased old fields and on very susceptible varieties.

As cacao cultivation becomes more intensive so will this control method increase in efficiency.

Pod losses are considered to be due to infection by basidiospores from a nearby source. They can be controlled within a field even if surrounding fields are heavily infected.

Brooms often result from infection arising at a more distant source. To reduce them, control must be carried out over larger areas than those necessary to control pod infection.

(*Received June 1954*)

REFERENCES

Baker, R. E. D., and Crowdy, S. H. (1943). 'Studies in the witches' broom disease of cacao caused by *Marasmius perniciosus* Stahel', Pt. I. Introduction, symptoms and etiology, *Imp. Coll. Trop. Agriculture, Trin., Mem. No.* 7

BAKER, R. E. D., and CROWDY, S. H. (1944). 'Studies in the witches' broom disease of cacao caused by *Marasmius perniciosus* Stahel', Pt. II. Field studies and control methods, *ibid.* No. 8
— and DALE, W. T. (1944*a*). 'Witches' broom disease investigations VIII', *Trop. Agriculture, Trin.*, **21,** 170–175
— — (1944*b*). 'Witches' broom disease investigations IX', *ibid.*, 175–176
— — (1944*c*). 'Witches' broom disease investigations X', *ibid.*, 196–198
— CROWDY, S. H., and THOROLD, C. A. (1941). 'Witches' broom disease investigations I', *ibid.*, **18,** 107–116
BRITON-JONES, H. R., and CHEESMAN, E. E. (1931). 'Witches' broom control', *ibid.*, **8,** 79–89
GREGORY, P. H. (1945). 'The dispersion of airborne spores', *Trans. Brit. mycol. Soc.*, **28,** 26–72
— (1952) Presidential Address, 'Fungus spores', *ibid.*, **35,** 1–18
INGOLD, C. T. (1949). 'Spore dispersal in relation to plant disease and health', *Sci. progr.* **37,** 644–656
STAHEL, G. (1915). '*Marasmius perniciosus* nov. spec.' *Bull. Dep. Landb. Suriname, No.* 33
STELL, F. (1932). *Annu. Rep. Dept. Agric. Trinidad and Tobago*, 1931 (publ. 1932)
THOROLD, C. A. (1943*a*). 'Witches' broom disease investigations V', *Trop. Agriculture, Trin.*, **20,** 176–181
— (1943*b*). 'Witches' broom disease investigations VII', *ibid.*, 239–241

The Status of Bovine Trichomoniasis in the Colony of Trinidad and Tobago

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INTRODUCTION

Trichomonas foetus, or more correctly *Tritrichomonas foetus*, is a flagellated parasitic protozoan found in the genital tract of cattle. Its distribution is probably world-wide, wherever cattle are found.

In the male, the organism is located mainly in the preputial cavity but it has been found within the epididymis and seminal vesicles. In the female, the parasite occurs in the uterus, cervix and vagina. The infection is permanent in the bull, despite treatment, but often dies out without treatment in the female, after sexual rest for three heat periods.

The disease is invariably spread by coitus and is characterized by sterility, or failure to conceive after repeated services, abortion and pyometra. It is, in fact, a very costly disease. The only certain control in an infected herd is to resort to artificial insemination.

The parasite was first demonstrated in Trinidad in 1950, by the author, and this paper presents the findings of a survey made to determine the distribution of the organism amongst service bulls in the Colony.

METHODS AND MATERIALS

Tobago

The swab method was adopted in the island-ward of Tobago on account of the absence of facilities for centrifuging preputial washings. The material was examined within two hours of its being secured. Culture medium was not available.

Trinidad

Both the swab and douche methods were employed in Trinidad as well as the inoculation of medium in the case of negative direct examinations. One hundred to one hundred and fifty millilitres of physiological saline were used in douching and the fluid centrifuged to approximately 3 to 4 ml. at 2,000 r.p.m. for 15 min. Only material secured by douching was used as inoculum; 0·5 ml concentrated washing in duplicate tubes, along with 5,000 units of streptomycin per millilitre of total fluids in the inoculated tube of medium. Tubes were sealed with a layer of liquid paraffin, after inoculation, and incubated at 37°C for 72 hrs. Both tubes were examined on the third day by withdrawing a drop of sediment and, if this proved negative, the fluid contents of the tubes were centrifuged as before and examined.

The Pierce (1951) medium was used throughout this survey and each batch was tested before being used for diagnostic purposes by inoculating tubes with approximately 10 organisms from washings of an infected bull.

If the medium was satisfactory, organisms could be readily found on the third day in a drop of fluid taken from the bottom of a tube.

RESULTS

The findings and distribution of the bulls examined in Tobago are presented in *Table 1* and *Figure 1*, while *Table 2* and *Figure 2* deal with Trinidad.

Table 1. Results in Tobago

No. of bull	*Birth date*	*Examinations*								
		First			*Second*			*Third*		
		Date	*Method*	*Result*	*Date*	*Method*	*Result*	*Date*	*Method*	*Result*
1	15/10/42	5/3/52	*Swab*	N	23/4/52	*Swab*	N	9/6/52	*Swab*	N
2	15/8/47	27/12/51	,,	N	7/5/52	,,	N	14/7/52	,,	N
3	1/2/48	14/12/51	,,	N	7/5/52	,,	N	14/7/52	,,	N
4	13/12/47	2/10/52	,,	N	19/12/52	,,	N			
5	14/3/47	26/6/52	,,	N	17/7/52	,,	N	27/8/52	,,	N
6	21/3/43	29/2/52	,,	N	24/4/52	,,	N	14/7/52	,,	N
7	23/9/39	14/1/52	,,	N	24/4/52	,,	N	14/7/52	,,	N
8	6/1/43	28/2/52	,,	N	23/4/52	,,	N	9/6/52	,,	N

Key: N = Negative

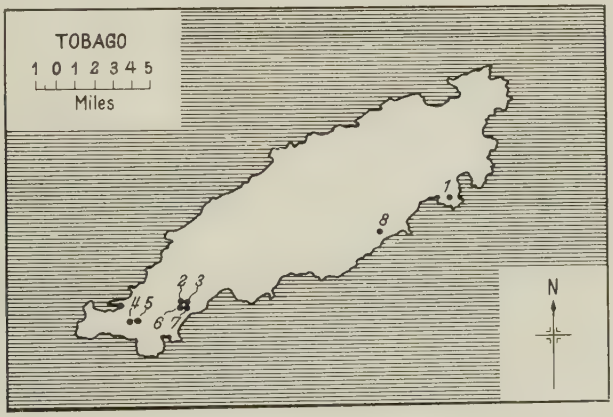

Figure 1

DISCUSSION

Twenty-three examinations of eight stud bulls located in the cattle areas of Tobago failed to reveal the presence of *T. foetus*. In Trinidad 15, or 82·2 per cent of the 18 bulls examined, were found to be infected with the organism. Since the 18 bulls were available to and were used by the public, it must be concluded that trichomoniasis is widespread and a problem in Trinidad. It should be noted that 13 of the 15 positive bulls in Trinidad were detected at the first examination and one at the third examination, employing the swab method. Although no definite conclusion of freedom from the disease can be drawn for Tobago, it appears that trichomoniasis is rare. There is practically no cattle traffic into Tobago.

Table 2. Results in Trinidad

No. of bull	Birth date	Examinations											
		First			Second			Third			Fourth		
		Date	Method(s)	Result	Date	Method	Result	Date	Method(s)	Result	Date	Method(s)	Result
1	17/10/47	11/3/53	*Swab*	P									
2	27/5/48	17/3/53	,,	P									
3		17/3/53	,,	P									
4	28/8/44	17/3/53	,,	P									
5		10/11/50	,,	N	15/12/50	*Swab*	N	17/3/53	*Swab*	P			
6	31/12/41	8/11/50	,,	P									
7	12/12/49	26/3/53	,,	P									
8	18/1/51	26/3/53	,,	N	23/6/53	*Douche*	N	23/2/54	*Douche* *Cultured*	N			
9	17/6/49	15/4/54	*Douche* *Cultured*	N									
10	28/6/46	10/4/53	*Swab*	P									
11	29/11/47	10/4/53	,,	P									
12	26/12/48	10/4/53	,,	P									
13		20/4/53	,,	P									
14	26/7/47	20/4/53	,,	P									
15		20/4/53	,,	N	23/6/53	*Douche*	N	1/2/54	*Douche*	N	23/2/54	*Douche* *Cultured*	N
16	22/10/43	24/6/53	,,	P									
17	25/1/46	24/6/53	,,	P									
18		3/12/53	*Douche*	P									

Key: P = Positive
N = Negative

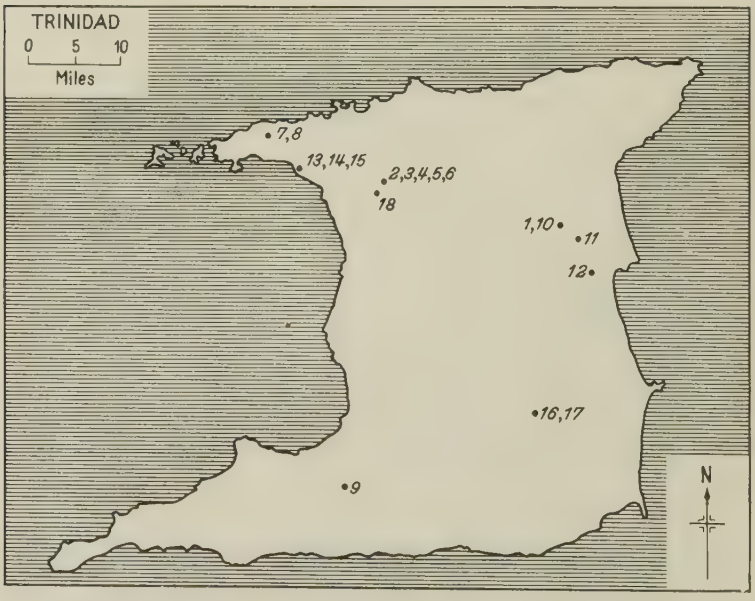

Figure 2

SUMMARY

Results of a bovine trichomoniasis survey amongst bulls in the Colony of Trinidad and Tobago are presented. Fifteen out of eighteen stud bulls in public service in Trinidad were infected, while the organism was absent from eight such bulls in Tobago.

(*Received June 1954*)

REFERENCE

PIERCE, A. E. (1951) *Private commun.*

*The Effect of some Fertility Treatments on the Yield and Fibre Quality of Sansevieria in South Florida**

E. O. Gangstad, J. F. Joyner and C. C. Seale†

INTRODUCTION

Sansevieria has been grown experimentally in South Florida as a potential cordage fibre crop for a number of years. While there are still many factors limiting commercial production, considerable progress has been made in the solution of basic problems (Bair, 1945; Byrom, 1950-51; Robinson and Joyner, 1948; Toro, 1942).

Preliminary investigations indicated that the long petiolate species such as *S. trifasciata* Prain and *S. thyrsiflora* Thunb. had the greatest potential for fibre production because they are readily propagated by leaf cuttings, have a comparatively long length of leaf, develop a relatively dense stand, and recover well after cutting (Crane and Alonso, 1945; Gangstad, Joyner and Seale, 1951; Joyner, Gangstad and Seale, 1950).

While most species of sansevieria are injured by cold in south Florida, *S. trifasciata* is fairly tolerant of cold, and the degree of frost injury may be reduced by proper fertilization, clean cultivation and selection of the warmest sites for production (Gangstad, Joyner and Seale, 1953).

Weed competition has been a major problem because of the relatively slow growth of the plant and the long period of growth required to develop a stand, but most weeds can be controlled by proper application of herbicides (Gangstad, Seale and Joyner, 1953).

The soils studied for production of sansevieria in south Florida are light sandy soils having low natural fertility, subject to serious leaching during the high rainfall of the summer and early fall months (*Fla. agric. Exp. Sta. Bull.*, 1945). The results of NPK fertility treatments on Leon fine sand, the frequency of application of fertilizer on Davie fine sand, and the effects of fertility treatments on fibre quality are presented in this paper.

LEVEL OF FERTILIZER APPLICATION

The response to NPK fertilizer application was studied in a $3 \times 3 \times 3$ factorial experiment on Leon fine sand near Boynton, Florida. Nitrogen was applied as Uramon at 0, 75 and 150 lb. N per acre, potash was applied as muriate of potash at a rate of 0, 50 and 100 lb. K_2O per acre, and phosphate was applied as triple superphosphate at a rate of 0, 50 and 100 lb. P_2O_5 per acre. The minor elements copper, manganese and zinc were applied as

* Studies of the Section of Cotton and Other Fibre Crops, Field Crops Research Branch, Agricultural Research Service, U.S. Department of Agriculture, with the Mechanical Processing Section and the University of Florida Everglades Experiment Station cooperating. Published with the approval of the Director of Field Crops Research Branch and the Director of the Florida Experiment Station. *Fla. Agric. Exp. Sta. Jnl. Series No.* 276.

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the sulphates at 25, 25 and 10 lb. per acre respectively. Boron was applied as Borax at 5 lb. per acre.

The experimental site had been previously cropped with pineapples and had been fertilized with frequent applications of a 4–7–5 fertilizer mixture and dolomite limestone. Soil tests at the beginning of the experiment indicated an average pH of 5·5, 16 lb. per acre water soluble P and 66 lb. per acre dilute acid soluble K.

The experiment was planted in December 1948 with young *S. trifasciata* plants 6 to 8 in. high, set out in rows 20 in. apart and spaced about 12 in. in the row. Plots were set up without alleys, 10 × 13 ft. in area in a 3 × 3 × 3 factorial design of two blocks and six sub-blocks, a total of 54 plots. Weeds were controlled by hand pulling each month. Fertilizer treatments were applied each year during the month of March.

Growth of the sansevieria was not very rapid. It is assumed that growth was somewhat retarded by intermittent drought. There was no apparent loss of fibre from disease and only slight injury from cold. About two years were required to develop the stand. The yields obtained from leaves over 20 in. in length are largely the result of the third year growth.

The sansevieria was harvested three years after planting by means of a Gravelly mower and was cut as close to the ground as possible. Total green weight and the weight of leaves over 20 in. in length were taken in the field. A sample of 20 to 25 average length leaves was taken for fibre analysis and the fibre was extracted by means of a small raspador type decorticator.

Soil samples were taken as four sub-samples per plot from the surface 6 in. layer. Soil tests for phosphate and potash were made in the soils laboratory at Belle Glade according to methods of FORSEE (1951) for this area.

A summary of the yield and soil tests data is given in *Table 1*. The yield of total green material, total dry fibre and dry fibre from leaves over 20 in. in length was significantly increased by the application of nitrogen and potash.

Table 1. Summary of Yield and Soil Test Data for a 3 × 3 × 3 NPK Factorial Experiment with Sansevieria trifasciata, *on Leon Fine Sand Near Boynton, Florida, Harvested 3 years after planting*

Treatment lb./acre		*Yield.* 1000 *lb./acre*			*Soil tests lb./acre*	
		Total green material	*Total dry fibre*			
			From all leaves	*From leaves over 20 in.*	P	K
N	0	18	·18	—	10	12
	75	35	·52	·080	12	11
	150	57	1·05	·346	11	10
P_2O_5	0	38	·52	·333	8	11
	50	38	·59	·330	12	11
	100	34	·64	·313	13	11
K_2O	0	21	·31	—	10	7
	50	39	·61	·172	11	11
	100	50	·83	·254	12	15
LSD	·05	9	·68	—	2	3
LSD	·01	12	·92	—	3	4

At the zero level of application of nitrogen and potash there was very little growth. At the intermediate level, there was some vegetative growth, but few leaves were over 20 in. in length. About a third of the leaves were over 20 in. in length at the high level of application.

The application of phosphate did not significantly affect yield although the level of phosphate in the soil was significantly increased by the phosphate treatment. The level of potash in the soil was increased by the potash treatments, but the soil content of potash in all treatments was very low.

The results indicate that at least 150 lb. of nitrogen and 100 lb. of potash are required per acre for satisfactory growth and further increases in yield can be expected from higher rates of application. It is assumed that applications of phosphate would be required with continued cropping.

FREQUENCY OF FERTILIZER APPLICATION

The effect of the frequency of fertilizer application was studied in a 5×5 graeco-latin square experiment of five varieties and five fertility treatments on Davie fine sand near Fort Lauderdale, Florida. Fertilizer was applied as a 12–8–8 mixture at a rate of 1000 lb. per acre per year for three years. Nitrogen in the mixture was applied as one-half Uramon and one-half nitrate of soda, phosphate as basic slag, and potash as muriate of potash. The total application of 3000 lb. in three years of 12–8–8 was split into five treatments: two applications, once every 18 months; three applications, once every 12 months; six applications, once every six months; nine applications once every four months; and 18 applications, once every two months.

The experimental site had been previously cropped to market grade vegetables with frequent applications of nitrate of soda. Soil tests indicated a pH of 7·8, 2 lb. per acre water soluble P and 15 lb. per acre dilute acid soluble K.

The experiment was planted in July 1950 from whole plants about 12 in. high at a rate of one plant per square foot. Plots were set up without alleys, 6×9 ft. in area in two 5×5 graeco-latin squares, a total of 50 plots. Weeds were controlled by application of CMU at a rate of 6 lb. active ingredient per acre as needed. Fertilizer treatments were applied by hand according to the prescribed schedule of application. Growth was somewhat retarded by drought and there was moderate disease injury, but there was no apparent loss of fibre from cold or frost. Approximately 18 months were required to develop a stand.

The leaves were harvested by hand at the end of three years. Green weights per plot were taken in the field for leaves under 20 in. in length and leaves over 20 in. in length. A sub-sample of about 10 lb. green leaves over 20 in. in length was taken for fibre analysis and the fibre extracted by means of a small raspador hand fed decorticator.

Yield and soil test data of this experiment are summarized in *Table 2*. The yield of green material and dry fibre was significantly increased by application of fertilizer at least every four months. There was very poor growth and yield in plots where fertilizer was applied only once every 18 months.

Table 2. Summary of Yield and Soil Test Data for a 5×5 Graeco-latin Square Experiment for Frequency of Fertilizer Application and Varieties on Davie Fine Sand Near Fort Lauderdale, Florida, Harvested 3 years after Planting. Total Application of 3000 lb. per acre of 12–8–8 for 3 years in All Treatments

Treatment	Yield. 1000 lb./acre			Soil tests lb./acre	
	Total green material		Dry fibre from leaves more than 20 in.		
	From leaves less than 20 in.	From leaves more than 20 in.		P	K
Frequency of application					
2 *months*	124	99	1·16	3	36
4 *months*	122	87	1·17	3	33
6 *months*	109	46	·54	2	24
12 *months*	87	45	·53	2	25
18 *months*	91	31	·37	2	24
Species of Sansevieria					
longiflora	70	85	1·12	2	30
thyrsiflora	83	68	·97	3	33
trifasciata	141	63	·80	2	24
laurentii	148	61	·49	2	25
liberica	90	31	·39	3	31
LSD ·05	29	26	·34	NS	8
LSD ·01	39	35	·47	—	12

The fibre yield of *S. longiflora*, *S. thyrsiflora* and *S. trifasciata* did not differ significantly, but the yields of *S. trifasciata* var. *laurentii* and *S. liberica* were significantly lower, about one-half the yield of the above varieties.

The yield of green material from leaves less than 20 in. in length was significantly higher in *S. trifasciata* and *S. trifasciata* var. *laurentii* than in other species. It is assumed that the stand was not mature and that the yield of fibre would increase at a more rapid rate in subsequent years.

FIBRE QUALITY

The effect of fertility treatments on fibre quality was studied by laboratory determinations for strength, shear, wear and flex according to the methods of BERKLEY *et al.* (1949), using the ½ in. break length for strength and the SS twist for wear. Fibre bundles 15 in. long weighing 325 mg were made up in the fibre laboratory at Belle Glade under standard conditions of 70° F temperature and 65 per cent relative humidity. In the NPK factorial, five breaks per bundle and two bundles per plot were made for strength; two breaks per bundle, five bundles per plot were made for shear; and three determinations per plot for wear and flex.

In the graeco-latin square experiment, five breaks per bundle and one bundle per plot were made for strength; two breaks per bundle and one bundle per plot for shear; and one determination per plot for wear and flex.

The results of these tests are summarized in *Table 3*. On Leon fine sand, there was a significant trend for nitrogen and potash treatments to increase strength and decrease wear and flex, but these effects were not large. On Davie fine sand, the frequency of application did not have significant effects. Variety effects were statistically significant, but these differences were not

large. The wear and flex values were somewhat higher on Leon fine sand than on Davie fine sand, but these differences also are not considered large enough to affect utilization of the fibre.

Table 3. Summary of Fibre Quality Tests for Fertility Experiments on Leon Fine Sand Near Boynton, Florida (1949–51) and Davie Fine Sand Near Fort Lauderdale, Florida (1950–53).

Treatment		1000 *lb./sq. in.*		1000 *cycles to failure*	
		Strength	*Shear*	*Wear*	*Flex*
LEON FINE SAND NEAR BOYNTON					
lb./acre					
	0	49	11	3·1	9·4
N	75	51	12	1·3	7·9
	150	52	12	1·6	7·7
	0	50	12	2·0	7·4
P_2O_5	50	50	12	2·4	8·9
	100	52	12	1·6	8·7
	0	50	11	2·1	9·5
K_2O	50	51	12	2·4	8·7
	100	51	12	1·5	6·9
LSD ·05		2	NS	1·1	2·6
LSD ·01		3		1·5	3·4
DAVIE FINE SAND NEAR FORT LAUDERDALE					
Frequency of application					
2 *months*		49	13	·8	5·6
4 *months*		50	14	·5	4·9
6 *months*		48	15	·6	5·0
12 *months*		48	14	·5	5·7
18 *months*		50	14	·8	5·0
Species of Sansevieria					
longiflora		54	16	·5	6·5
thyrsiflora		46	15	·7	6·4
trifasciata		50	12	·4	3·9
laurentii		50	14	·5	4·7
liberica		44	14	·8	4·7
LSD ·05		7	2	NS	1·7
LSD ·01		10	3		2·3

SUMMARY

Experimental yields, soil content of phosphate and potash and fibre quality were studied in a 3 × 3 × 3 factorial experiment for level of application of NPK on Leon fine sand and in a 5 × 5 graeco-latin square experiment for frequency of application on Davie fine sand.

The yield response to the application of nitrogen and potash on Leon fine sand was highly significant, but there was little response to phosphate. Soil tests gave moderate levels of phosphate and very low levels of potash. The results indicate an annual application of at least 150 lb. nitrogen and 100 lb. of potash per acre. Phosphate may be required with continued cropping.

The response to frequency of fertilizer application on Davie fine sand was highly significant. The yield was approximately doubled by split

application, every four months or less. Soil tests showed a significantly higher level of potash by application at this frequency. The results indicate fertilizer should be applied at least every four months for satisfactory utilization.

Differences in fibre quality due to various treatments were in many cases significant, but are not considered large enough to affect utilization of the fibre.

(*Received July 1954*)

REFERENCES

BAIR, R. A. (1945). 'Fiber crop investigations', *Annu. Rep. Fla. agric. Exp. Sta.*, pp. 208–9

BERKLEY, E. E., HESSLER, L. E., BURNESTON, E. B., and CHEW, C. F. (1949). 'A study on the quality of abaca fiber', *Tech. Bull. U.S. Dep. Agric. No.* 999

BYROM, M. H. (1950–51). 'Progress with long vegetable fibers', *Yearb. Agric.*, 472–476

CRANE, J. C., and ALONSO, R. E. (1945). 'Fiber content in relation to length and age of *Sansevieria thunb.* leaves', *Jour. Amer. Soc. Agron.*, **37**, 953–961

'Florida. Soils, geology and water control in the Everglades region', *Bull. Fla. agric. Exp. Sta. No.* 442 (1945)

FORSEE, JR., W. T. (1951). 'The place of tissue testing in evaluating fertility levels under Everglades conditions', *Proc. Soil Sci. Soc. Amer.*, **15**, 297–299

GANGSTAD, E. O., JOYNER, J. F., and SEALE, C. C. (1951). 'Agronomic characteristics of sansevieria species', *Trop. Agriculture, Trin.*, **26**, 204–214

— — — (1953). 'The effect of cultural treatments on the frost injury and growth of sansevieria in south Florida', *Trop. Agriculture, Trin.*, **30**, 171–177

— SEALE, C. C., and JOYNER, J. F. (1953). 'Preliminary studies in the use of herbicides for control of weeds in sansevieria', *Weeds*, **2**, 113–118

JOYNER, J. F., GANGSTAD, E. O., and SEALE, C. C. (1950). 'The vegetative propagation of sansevieria', *Agron. J.*, 43, 128–130

ROBINSON, B. B., and JOYNER, J. F. (1948). 'Sansevieria', *U.S. Dep. Agric. Mimeo. Rep.*

TORO, AUGUSTO PEREZ (1942). 'El cultivo de la sansevieria en Yucatan', Publicaciones de Fomento de Yucatan. *Merida de Yucatan*

The Use of Pot Tests in Research on the Fertility of Sugar Cane Soils

Paper VI: The Effect of Increasing Phosphate Dressings and Various Methods of Placement on the Phosphate Status of Red Ferruginous Clay and on the Growth of Cane

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INTRODUCTION

Sugar cane plants were grown to maturity in 40 gal. oil-drums, in a pot test of Type 2 described in Paper I of this series. The test was conducted with a large sample of ' Talparo Red Clay ' collected from Hermitage Estate belonging to the Ste. Madeleine Sugar Company, Trinidad. This soil is related to Tropical Red Podzol, and is a much leached, highly acid, non-calcareous, base-deficient clay, covering a large area of the sugar cane belt in Trinidad. A full discussion of this soil-type, with special reference to its lime and potash requirement, is offered in Paper II of this series, the same batch of soil being used in both experiments. In the past, the phosphate deficiency of this soil type has been stressed by various authors. Turner (1940) reported that small dressings of about 2 cwt. superphosphate per acre would give beneficial results. However, in those days only the hardy but low yielding Uba cane was grown which could stand the adverse conditions of this soil and accordingly, the use of fertilizers did not raise the average yields far above 20 tons per acre. Hardy (1941 and 1947), guided by the results of Mitscherlich pot tests with Sudan grass, recommended a ' high phosphate-high nitrogen ' policy with dressings of ammonium sulphate and superphosphate of the order of 10 cwt. per acre of each. These recommendations were followed up by the Field Superintendent of the Ste. Madeleine Sugar Company, who conducted a new series of field trials with noble cane (Potter, 1948). Optimum economic responses of plant canes were obtained to dressings per acre of 8 cwt. ammonium sulphate in combination with 6 and 3 cwt. superphosphate (20 per cent) for unlimed and limed soils respectively. However, these dressings were not continued, neither was lime included in the fertilizer programme of the following years and routine estate policy settled down to annual dressings, for both plant and ratoon cane, of 3 cwt. superphosphate and 6 cwt. ammonium sulphate. From this experimental work a number of practical and theoretical questions arose, which demanded further research. The drum test technique offered itself as the most suitable method to study this variety of problems under rigidly standardized and closely controlled conditions and the following investigations were undertaken.

First of all it seemed of great practical importance to assess the optimum phosphate status for this soil, by means of a chemical soil analytical method. To this end, sub-batches of soil were phosphated to various degrees, by mixing the soil intimately with phosphate solutions of increasing strengths.

In this way soils with four different phosphate levels were prepared, each being well defined by a distinct, reproducible ' Truog value ' for available phosphate. Afterwards, by comparing leaf analytical data for phosphate uptake and final yield figures for those four soils, the optimum Truog value could be chosen.

The dosages of water soluble phosphate, thus incorporated into the soil of each drum, were equivalent to field dressings of 0, 3, 6 and 9 cwt. superphosphate (20 per cent) per acre of 4,000 plants. Parallel to this ' standard series ', denoted below by ' M0 ' three other series (M1, M2 and M3)were prepared. In each series the same four dosages of water soluble phosphate, all derived from double super (40 per cent), were used but were applied in different ways.

In the second series (M1) the dissolved phosphate was added only to the top half of the soil contained in each drum, doubling the Truog value in this top layer. The purpose of this treatment was to measure the relative effectiveness of a higher phosphate status in the soil in which the contact area between the absorbing root surface and the phosphated soil surface was reduced. This might answer the practical question whether a higher Truog value than normal must be aimed at for soils in which adverse conditions confine the cane roots to shallow soil layers.

In the third series (M2) the four dosages of phosphate were applied in powdered form at the bottom of the furrow, in a thin layer of 6×6 in. square, and covered with 2 in. of soil before planting the seed piece on top of it. The purpose of this treatment was to compare the effectiveness of ' concentrated phosphate placement ', so often advocated to off-set the alleged losses through ' fixation ' by the soil, with the standard treatment in which this ' fixation ' could be expected to be most severe. In the fourth series (M3), the superphosphate dosages were given according to estate practice, in powdered form on top of the soil near the young plant.

In an attempt to exaggerate the effects of delayed phosphate dressings, often encountered under the present field practice, the phosphate was applied three months after planting. Finally, the factor lime* was included in the experimental programme. Although the beneficial effects of liming on the growth of cane and the uptake of phosphate and other nutrients have been proved already for this soil-type by the experimental data presented in Paper II of this series, the conflicting statements, in previously quoted literature, on the interaction between lime and phosphate and the influence of lime on the phosphate fixation, made it desirable to include a special study of the liming effect in this experiment.

To this end, each of the four phosphate treatments series was repeated with soil previously mixed with finely powdered limestone. The $4 \times 4 \times 2$ treatment combinations were replicated three times and arranged according to factorial design as described in *Iowa Bull.* No. 333, p. 464.

EXPERIMENTAL PROCEDURE

General Technique

A large amount of top-soil (top 12 in.) was collected from a freshly ploughed experimental site in the field (H43), which had never received any

* Throughout this article the term lime denotes calcium carbonate.

phosphate, lime or potash dressing in the past. The soil was spread out on a concrete floor in the open air and exposed to sun and weather so as to dry and disintegrate the lumps. Remaining lumps were hand crushed and the whole soil was passed through a large, half-inch sieve. Thereafter it was thoroughly mixed, sun-dried, remixed and finally divided into 96 equal portions of 110 kg (=243 lb.) air-dry soil, each being a drum filling. Half of this number was thoroughly mixed with lime. The amount used (10 g calcium carbonate per kilogram) is equivalent to three times the theoretical lime requirement that would bring the reaction of the soil to pH 6·5. The sub-batches were all packed in jute bags marked and stored indoors until needed. In the meantime, 96 drums were set up on sloping land in three blocks of 32 drums. The 12 sub-blocks of eight drums were aligned on the slope 12–14 ft. apart along the contour line and 10–12 ft. apart in the row (see *Figure 3*). Each drum was placed so that its bottom had a slight fall towards the 2½ in. drainage hole and a layer of coarse gravel was applied at the bottom of the drum so as to facilitate the drainage. Each drum was marked with a number of three figures, indicating the treatment combinations. The first figure (0, 1, 2 or 3) stood for the phosphate dosage ' P ':

P0=0
P1= 7·6 g or 19 g superphosphate (40 per cent) per drum.
P2=15·2 g or 38 g ,, ,, ,,
P3=22·8 g or 57 g ,, ,, ,,

The second figure (0, 1, 2 or 3) stood for the method of placement ' M ':

M0=phosphate mixed through the whole of 110 kg air-dry soil.
M1=phosphate mixed through top half (=55 kg) of air-dry soil.
M2=phosphate placed 2 in. underneath seed piece.
M3=phosphate applied on top of the soil three months after planting.

The third figure (0 or 1) stood for liming ' L ':

L0=no lime.
L1=1100 g $CaCO_3$ applied per drum and mixed with soil before P-treatments were carried out.

At this stage, the filling of the drums could be undertaken according to the methods set out in Paper I. From each filling, belonging to the M0 and M1 series, a soil sample was taken immediately after the phosphate solutions were added to the soil.

Each sample of 2 lb. consisted of about 25 small portions taken from various parts of the phosphated soil batch. These samples, eight triplicates for the limed and eight triplicates for the unlimed soil in total, were air-dried and analysed for their Truog value (*Table 1*). The series M2 and M3 did not receive any phosphate until one day before planting and three months after planting respectively. To prepare for planting, a small square platform, measuring 6 × 6 in., was shaped in the soil in the centre of each drum at a level of 9 in. below the rim of the drum, and the remaining soil was worked into a conical bank around it. After applying the M2 treatments, all drums received a top dressing of 25 g ammonium sulphate and 25 g muriate of potash dissolved in a gallon of water. The drums were planted up the next day (1 October 1952). The cane variety used was B 37–172. For each block a batch of 32 three-eye cane tops of equal size was selected

Table 1. 'Truog Values' Recovered from Soils Treated with Increasing Phosphate Dosages

Soil samples from Block No.	Added phosphate: Treatment No.	Dosage P_2O_5 grammes	Expressed as p.p.m. P_2O_5 per 110 kg M0	Expressed as p.p.m. P_2O_5 per 55 kg M1	Recovered available (Truog) phosphate: Expressed as p.p.m. P_2O_5 — Method M0 (110 kg soil): No lime	Method M0 (110 kg soil): Limed	Method M1 (55 kg soil): No lime	Method M1 (55 kg soil): Limed	Average
B.I	P0	0	0	—	16	16			
B.II					—	—			
B.III					17	18			17
B.I	P1	7·62	70		40	47			
B.II					42	40			44
B.III					47	46			
B.I	P1	7·62		140			78	74	
B.II							78	76	75
B.III							74	72	
B.I	P2	15·24	140		76	84			
B.II					74	71			79
B.III					84	82			
B.I	P2	15·24		280			140	150	
B.II							150	152	147
B.III							138	156	
B.I	P3	22·86	210		118	120			
B.II					124	116			120
B.III					122	122			
B.I	P3	22·86		420			220	222	
B.II							204	210	220
B.III							240	224	

SUMMARY OF RESULTS

Added phosphate (Independent variable = X)	0	70	140	210	280	420 p.p.m.
Recovered phosphate (Dependent variable = Y)	17	44	77	120	147	220 p.p.m.
Calculated by regression equation:*						
$Y = 104{\cdot}4 + 34{\cdot}8\ (X - 2{\cdot}7)$ .....Y	10	45	80	115	150	219 p.p.m.
values used for X	0	1	2	3	4	6

* *Regression sign. for* P = 0·01

and soaked in water overnight. When planted, the cane top was divided into three single-eye pieces of 5 in. length which were placed along three sides of the platform and lightly covered with soil. The seedlings germinated very equally, all drums contained at least two and most drums had three healthy seedlings. After one month, the number of seedlings per drum was reduced to two. It was observed that root-systems of the extracted plants which had germinated in non-phosphated soil were thinner and inferior as compared with roots of plants germinated in phosphated soil batches. After nine weeks the banks were levelled off. The M3 treatment was carried out on 3 December, three months after planting. The phosphate was dropped on the surface of the soil in between the two stools and lightly covered with soil. At this time another top dressing of 25 g ammonium sulphate (= 2 cwt. per acre) was given to all plants. This treatment was repeated three more times during the following eight months in order to

maintain an optimum supply of nitrogen throughout the experiment. The canes were regularly trashed once every two months at the times when growth measurements were made. The trash was cut up and added as a mulch to the surface of the soil in each drum. From this time onwards, daily addition of two gallons of water per drum was made during dry spells. The P_2O_5 content of this water was such that, even with 250 days of regular watering, no more than 0·1 g P_2O_5 would have been added per drum. This quantity is, in comparison with the P1 dressing of 7·6 g P_2O_5, a negligible amount. The canes were reaped on 15 January 1954 when 15½ months old. During growth, the cane plants suffered from strong winds which had a desiccating influence on the plants and retarded their growth, especially during the dry season.

Measurements

Length measurements and tiller counts were made at regular intervals. Length of stem was measured between the seed piece and the last visible ' dew-lap '. In *Table 2(a)*, the results of the length measurements are given and in *Figure 1*, these data are displayed graphically. The tiller counts are presented in *Table 2(b)*. Statistical analysis of these growth figures, carried out to test the significance of treatment effects in some of these measurements, has been omitted owing to lack of space. Results, however, are mentioned in the text.

Table 2(a). Data for Stem Length

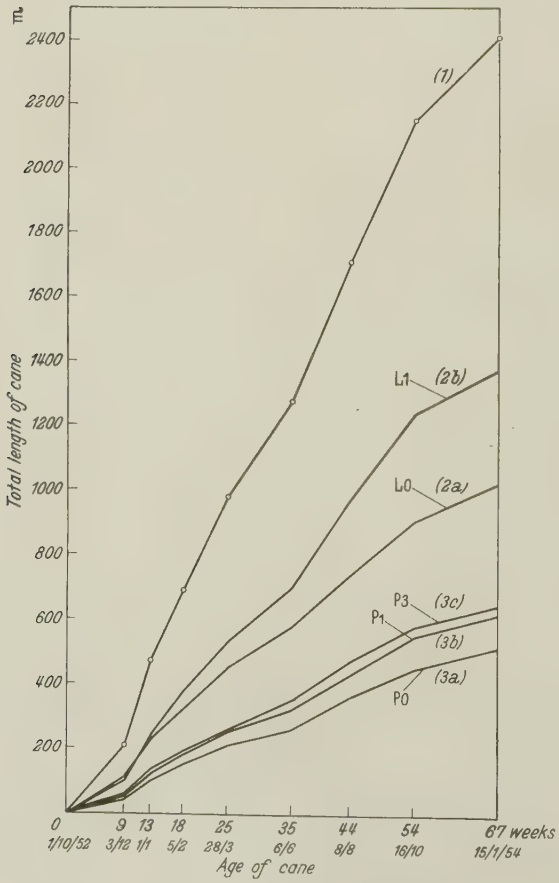
Index figures for total stem length per treatment (index of zero treatment fixed at 100)											*Average total stem length per drum (metres)*
Age of cane (weeks)	P0	P1	P2	P3	M0	M1	M2	M3	L0	L1	
9	100	131	139	160	100	97	95	73	100	91	2·16
13	100	124	120	130	100	101	88	79	100	104	4·90
18	100	117	121	123	100	101	87	87	100	115	7·23
25	100	121	126	128	100	103	94	94	100	116	10·23
35	100	123	131	134	100	105	98	98	100	120	13·37
44	100	121	127	132	100	103	96	100	100	127	17·83
54	100	123	125	129	100	106	98	100	100	135	23·49
67	100	119	121	127	100	105	98	101	100	133	25·13
Average treatment effect over 67 weeks	*100*	*122*	*126*	*133*	*100*	*103*	*94*	*91*	*100*	*118*	

Leaf Analysis

This was carried out after the canes were three months old and was repeated at an age of four months (13 weeks), six months (25 weeks) and eight months (35 weeks). Leaf collections were invariably made in the early morning. Two leaves were taken from the two longest stems in each drum. The third leaf from the uppermost leaf showing a ' dew-lap ' was selected. The treatment triplicate leaf samples were combined, the upper halves were cut off and discarded, the mid-ribs were stripped out and the remaining laminae were oven-dried and powdered in a hammer mill. As length

Table 2(b). Data for Tiller Coun

Age of cane (weeks)	Index figures for total tiller count per treatment (index of zero treatment fixed at 100)										Average number of shoots per drum	Average shoot length (metres)
	P0	P1	P2	P3	M0	M1	M2	M3	L0	L1		
9	100	123	123	140	100	94	95	76	100	96	10	0·22
13	100	120	117	127	100	102	90	83	100	103	18	0·28
18	100	111	115	119	100	101	89	89	100	111	22	0·33
25	100	111	121	118	100	105	99	100	100	108	25	0·41
35	100	110	115	118	100	99	99	98	100	132	16	0·84
44	100	112	113	117	100	101	98	97	100	115	14	1·23
54	100	113	112	115	100	101	97	99	100	124	13	1·72
67	100	105	108	108	100	96	101	102	100	129	14	1·75
Average treatment effect over 67 weeks	*100*	*113*	*115*	*120*	*100*	*100*	*96*	*93*	*100*	*115*		



In 96 drums for (*1*)
In 48 drums for (*2a*) and (*2b*)
In 24 drums for (*3a*), (*3b*) and (*3c*)

Age (weeks)	Length (metres)					
	(*1*)	(*2a*)	(*2b*)	(*3a*)	(*3b*)	(*3c*)
9	208	109	99	39	51	63
13	469	228	241	99	123	128
18	694	323	371	151	176	186
25	982	455	527	207	250	264
35	1284	583	701	263	323	352
44	1712	744	968	357	430	472
54	2146	910	1236	450	552	580
67	2412	1033	1379	516	616	655

Figure 1. Experimental growth measurements

measurements showed a trend for placement methods M0 and M1 to be very much alike in growth, the samples of these two treatments were also combined, so as to reduce the amount of analytical work. Phosphate and nitrogen were determined on the liquid obtained by wet digestion of 500 mg sub-samples. The results are set out in *Table 3* (*a*) and (*b*).

Table 3. Results of Leaf Analysis

Phosphate dosage P	*Placement method* M	*Age of cane plants* 13 weeks L0	13 weeks L1	18 weeks L0	18 weeks L1	25 weeks L0	25 weeks L1	35 weeks L0	35 weeks L1	*Average treatment effect over 35 weeks on nutrient level in leaves* *Treatment*	*percentage*
(*a*) *Phosphate content of leaf tissue* (*per cent* P_2O_5 *in oven-dry material*)											
P0	M0 1, 2, 3	0·34	0·40	0·28	0·31	0·23	0·27	0·25	0·30	L0	0·33
										L1	0·37
P1	M0+1	0·42	0·45	0·38	0·37	0·30	0·33	0·35	0·39	P0	0·30
	M2	0·37	0·41	0·33	0·38	0·29	0·34	0·34	0·36		
	M3	0·34	0·41	0·38	0·38	0·30	0·36	0·36	0·38	P1	0·36
P2	M0+1	0·41	0·46	0·37	0·42	0·30	0·33	0·37	0·41	P2	0·37
	M2	0·36	0·43	0·36	0·42	0·29	0·31	0·36	0·39		
	M3	0·34	0·40	0·42	0·42	0·33	0·34	0·36	0·39	P3	0·38
P3	M0+1	0·43	0·47	0·37	0·40	0·31	0·32	0·35	0·43	M0+1	0·38
	M2	0·43	0·43	0·35	0·41	0·31	0·37	0·35	0·40		
	M3	0·34	0·41	0·42	0·42	0·31	0·33	0·40	0·44	M2	0·35
Averages		0·40		0·38		0·31		0·37		M3	0·38
(*b*) *Nitrogen content of leaf tissue* (*per cent* N *in oven-dry material*)											
P0		2·34	2·47	2·02	2·03	1·55	1·57	1·58	1·54	P0	1·88
P1		2·30	2·42	1·96	1·92	1·40	1·70	1·34	1·45	P1	1·81
P2		2·33	2·42	1·86	1·96	1·47	1·52	1·55	1·62	P2	1·84
P3		2·21	2·39	1·82	1·91	1·45	1·54	1·34	1·64	P3	1·78
										L0	1·78
Averages		2·36		1·93		1·53		1·51		L1	1·88

Reaping and Milling the Cane

The stems were fully trashed and the stools cut off at seed piece level. The cane tops were also discarded and the remaining ' net millable cane ' was weighed. The yield data obtained are given in *Table 4*. Each of the 96 cane samples was separately crushed in a laboratory mill and the weights of juice were noted. The juice samples were analysed for ' degree Brix ', ' pol per cent ' and ' purity ', and the bagasse samples were analysed for ' pol per cent ' and ' moisture per cent '. From these data the ' pol in net cane per cent ' was calculated. As even the average treatment values presented in *Table 5* show very small differences, the 96 individual values are omitted.

Additional Tests

(*a*) Total phosphate was determined in the filtered, dried and ashed juices. The results are recorded in *Table 6*.

Table 4. Data for Millable Cane (lb.)

Three-way table

Placement methods	*Phosphate treatment.*						*Lime treatment*	
	P0	P1	P2	P3	*Total*	%	L0	L1
M0	99·00	125·50	145·00	142·00	512·50	= 100%	216·25	295·75
M1	111·00	141·50	156·00	150·50	559·50	= 109%	235·50	324·00
M2	100·75	136·00	139·25	133·50	509·50	= 100%	226·00	283·50
M3	105·75	136·75	132·75	145·50	520·75	= 102%	231·75	289·00
L0	165·25	238·50	257·75	248·00	909·50	= 100%		
L1	251·25	301·25	315·75	324·00	1192·25	= 132%		
Total	416·50	539·75	573·50	572·00	2101·75 G.T.			
Index	100%	130%	140%	140%				

Statistical Analysis

Treatments	*D.F.*	*M.S.*	*F.*
Blocks	2	64·3	5·3*
P	3	229·9	19·0†
M	3	22·5	1·9
L	1	832·8	68·8†
P × M	9	0	—
P × L	3	6·8	—
M × L	3	10·4	—
Error	71	12·1	

Precision experiment:

$\sqrt{(12{\cdot}1 \times 100) : 21{\cdot}9} = 15{\cdot}9\%$

Significant difference for P *and* M *totals*

$1{\cdot}96 \times \sqrt{12{\cdot}1 \times 2 \times 24} = 47{\cdot}2$*

* P = 0·05 † P = 0·01

Table 5. Pol in Net Cane per cent

Treatment averages

P0	P1	P2	P3	M0	M1	M2	M3	L0	L1	*Mean*
15·69	16·04	15·95	15·96	15·91	16·02	15·90	15·85	15·91	15·92	*15·92*

Table 6. Total Phosphate in Clear Filtered Juices (P_2O_5 p.p.m.)

Three-way table (derived from 32 independent observations)

Treatments	P0	P1	P2	P3	*Average* M *and* L *effect*	
M0	40½	97½	162	174	119 p.p.m.	100%
M1	41	103½	162½	171½	120 p.p.m.	100%
M2	37½	82	108	134½	91 p.p.m.	76%
M3	42½	107½	152	130	121 p.p.m.	100%
L0	41½	74	127	132	93 p.p.m.	100%
L1	39	122	165	198	131 p.p.m.	140%
Average P *effect*	40	98	146	165		
Index	100%	243%	362%	409%		

(*b*) Clarification tests were carried out on 24 juices representing triplicates of the eight M0-treatments: P0, P1, P2, and P3 with and without lime. The samples (500 cc each) were sterilized with mercuric chloride and were frozen immediately after the juice was collected from the mill. All samples were

defrosted on the same day when making the test. Aliquots of the triplicates were combined and for each of the eight juices, one litre of juice was limed to pH 8, heated to boiling and the settling and thickening curves estimated as described by SCHMIDT (1953). In *Table 7* and *Figure 2*, the relationship is presented between rate of settling and thickening of the mud and the phosphate contents of the juice (*Table 6*), as caused by phosphate and lime treatments.

Table 7. Relationship between Rate of Settling and Thickening and the Phosphate Content of the Juice

Treatments	P0	P1	P2	P3	
L0	41½	74	127	132	P_2O_5 p.p.m.
	4·6	4·4	6·8	6·7	H∞ (*mud-volumes*)
	8·1	9·5	18·5	13·5	R (*rate of settling*)
L1	39	122	165	198	P_2O_5 p.p.m.
	3·2	6·5	8·2	8·3	H∞ (*mud-volumes*)
	9·5	10·0	22·5	28·2	R (*rate of settling*)

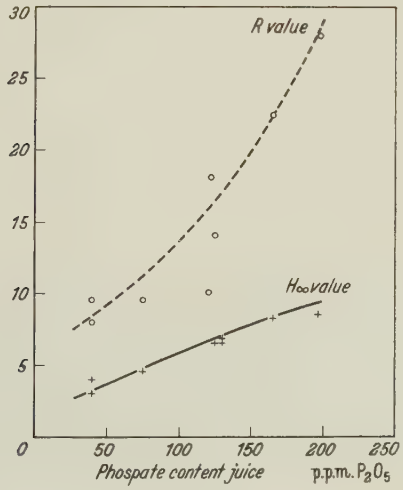


Figure 2.

CONCLUSIONS FROM EXPERIMENTAL DATA

The Phosphate Status of the Soil (*Table 1*).—It is of interest to note that for this soil, the relation between added water soluble phosphate (X) and available (Truog) phosphate (Y), can be represented by a straight line, given by the equation: $Y=104{\cdot}4+34{\cdot}8\ (X-2{\cdot}7)$, which is based on a highly significant regression of Y on X. All experimental values for Y are very close to the calculated ones, except for those belonging to zero or very low values of X. It is also noteworthy that preliminary liming in the L1 treatments, did not influence the Truog recovery values. This is contrary to the findings of HARDY (1947) who reported for this same soil an increased 'phosphate fixation' caused by liming. This investigator heated the aqueous suspension of soil with added portions of mono-sodium phosphate

and calcium bicarbonate to dryness on a waterbath, before the final Truog analysis. However, under these conditions the sodium phosphate turns into water insoluble dicalcium phosphate, whereas the reported 1·4 per cent free $CaCO_3$ present in 2 g soil, is adequate to neutralize the H_2SO_4 present in 400 cc Truog extraction liquid. Apart from the question whether any practical meaning can be attached to results obtained by an arbitrarily chosen ' phosphate-fixation ' test of this sort, it is very doubtful whether chemically measured ' phosphate fixation ' has any meaning at all as a gauge of that part of the soil's phosphate which is biologically unavailable to the plant. For this reason, no significance is attributed in this paper to the ' missing ' portion of the added phosphate but only to the final Truog value of the phosphated soil and its relation to cane growth.

Growth Measurements (Table 2 and Figure 1)

The general development of the cane in this experiment was quite regular. The rate of growth, however, was slow, due to the desiccating effect of a steady wind blowing into the open formation of cane plants. The windward block suffered most and showed a significant growth depression. From the Table it follows that the average number of shoots reached a peak of 25 after about six months. During the following four months this number came down to 14 with an average length of 1·75 m per shoot at the time of reaping.

Figure 3. General view of the experiment at reaping time

The phosphate treatments show the greatest difference in growth and tillering during the first three months. After nine weeks of growth there is a highly significant increase in stem length and tiller count for P1 over P0 and for P3 over P1. After 18 weeks of growth the P1 treatment is still highly significant over the P0 treatment, but neither P2 nor P3 is significantly better than P1. At the final age of 14½ months, P1 and P2 dosages gave 20 per cent more stem length and 51 per cent more tillers per drum than the P0 treatment. It seems that only in the early growth, when roots are still

confined to their nearest surroundings, do very high phosphate concentrations in the soil promote additional aerial development over moderate phosphate concentrations. Later on, when the root system explores much larger volumes of soil, the requirements of the plant will be met satisfactorily by a soil with a lower concentration of the order of the P1 dressing.

The methods of placement also show some interesting features. The M0 and M1 treatments are very much the same in the beginning, although towards reaping time, the M1 treatment tends to be the more effective one. The M2 treatment (concentrated placement method) is definitely inferior to the standard M0. Although the difference is not yet statistically significant at an age of nine weeks, it is highly significant when the canes are 13 and 18 months old. From that time onwards, the difference becomes less apparent and is practically nil at reaping time. It seems that in the period (two to six months) when rapid aerial development of the cane demands increasing supplies of phosphate, the requirements cannot be met because only a negligible part of the absorption surface of the expanding root system is in contact with the phosphated spot (SCHROO, 1953 (*a*)). The first two index figures for the M3 treatment are very low as they really represent P0 values. After the phosphate was surface-applied when the canes were 13 weeks old, growth and tillering improved rapidly and equalled those of the standard method M0 in a few months. The data for leaf analysis (*Table 3*) also confirms that, in two months, the arrears in P_2O_5 uptake were fully compensated. This surprising result can be explained by the fact that, under the special conditions of this experiment, a dense mass of new roots is developed by this cane variety near and at the surface, just around this age of three to five months. Apart from the fact that under field conditions the M3 treatment might have suffered heavy phosphate losses through surface wash, it is not at all certain that in the field, the same favourable conditions for root development and phosphate uptake at the soil surface would have prevailed.

The lime treatment L1 caused a depression in growth during the first two months. After this early stage, the beneficial influence of the L1 treatment steadily increases every month, until, at reaping time, it results in a striking improvement of stem length and tiller count over the L0 treatment of 33 per cent and 29 per cent respectively. The initial negative liming effect is difficult to explain and cannot be related to a depressive influence of lime on the uptake of P_2O_5 and N, as is shown by the leaf analytical data: 0·43 per cent P_2O_5 and 2·43 per cent N was found in the leaves for the L1 treatment and 0·37 per cent P_2O_5 and 2·30 per cent N for the L0 treatment.

Leaf Analysis (*Table 3*)

The point should be stressed that the figures for nutrient uptake are not absolute nutrient levels but have only relative value in comparing the treatment effects at any stage of growth. Seasonal growing conditions which, besides the nutrient supply, determine the absolute level of the nutrients in the leaves, are not constant for the whole of the experiment but do change during the growing period and shift the absolute values considerably, as may be seen from the averages for P_2O_5 levels at four different stages of growth. At 13 weeks' growth, the non-phosphated soil (P0 and all M3 treatments) is characterized by a P_2O_5 level of 0·34 per cent for the

unlimed and 0·40 per cent for the limed series in the case of M0 and M1 placement. These levels go up to 0·43 and 0·47 per cent respectively with the use of P3 dosages. The levels corresponding with P1 and P2 dosages are not much lower. The inferiority of the M2 placement shows up clearly at this stage. At 18 weeks' growth, five weeks after applying the phosphate in the M3 series, the phosphate levels found for this M3 treatment are extremely good, whereas the M2 treatment is still giving lower phosphate levels on the unlimed soil. In the subsequent sampling stages, treatment differences are less pronounced with the exception of those for non-phosphated versus phosphated and limed versus unlimed treatments. It should be remembered that after six months, the phosphate levels in the leafy part of the cane are more or less constant and changes in phosphate supply may be more clearly reflected by the phosphate status of the stem (DILLEWIJN, 1952). The nitrogen levels in the leaves were fairly constant for all treatments as shown by the averages in *Table 2(b)*. It should only be noted that these figures demonstrate the general rule, that low phosphate supply increases the N level in the leaves, whereas high phosphate supply exerts the reverse effect.

Final Yields of Millable Cane (Table 4)

The data in *Table 4* demonstrate that the yield response of sugar cane to phosphate and lime treatments, in terms of weight of net millable cane, is highly significant. With P1 dosages a yield increment of 30 per cent was obtained. The additional 10 per cent rise in yield resulting from either P2 or P3 dosages, however, was not significant. It should be observed that there is no significant interaction between phosphate and lime. There is a slight tendency to a negative interaction which means that the beneficial effects of each of the two treatments cannot be fully additive. This is quite understandable as liming acts, to a certain extent, as a phosphate dressing itself, in as far as it enables the roots to make a better use of available phosphate. The average effect of placement methods did not show significant response. However, the effect of M1, tried separately in a statistical test against the other three methods, proved to be significantly better (9 per cent). These findings lead to the conclusions:

(*a*) That mixing a given phosphate dosage intimately with a large volume of soil provides a phosphate supply to the plant which is equally effective as the concentrated 'placement' of the same phosphate dosage underneath the stool (M2) or on top of the soil (M3). Hence, the 'phosphate fixation' as determined by chemical tests, does not seem to reduce the availability of the phosphate to the plant roots at all.

(*b*) Mixing the same phosphate dosage with a smaller volume of soil, more particularly with the top 12 in. of soil, proves to be more effective.

(*c*) Statistical evidence suggests that for deep well aerated phases of this soil a Truog value of about 40 p.p.m. is adequate, but that for shallow phases a Truog value of about 75 p.p.m. should be aimed at.

Additional Tests (Tables 5, 6 and 7)

Cane quality as gauged by 'pol in net cane per cent' (*Table 5*), does not show differences of any significance for the various treatments.

Total Phosphate in clear filtered juices (*Table 6*) is most strikingly influenced by the lime and phosphate treatments. Lime increased the P_2O_5 concentration by an average of 40 per cent. In the case of the P0 treatment, this lime effect was absent due to the phosphate deficiency of the soil. The increments, caused by the treatments P1, P2 and P3 are most impressive, giving P_2O_5 concentrations of 98, 146 and 165 p.p.m. respectively against 40 p.p.m. for P0. A remarkable feature is the depression of the P_2O_5 content caused by the M2 treatment which shows up in all phosphate treatments (P1, P2 and P3) for the limed as well as for the unlimed series.

The clarification of the juices, as characterized by settling rate and mud volumes is related to treatments and corresponding P_2O_5 concentrations of juices in *Table 7*. The treatments P0 and P1 without lime and P0 with lime, produced very dark juices (Kopke Clarity: 15, 15 and 13 respectively). They are deficient in phosphate and would require additional phosphoric acid in the factory to give satisfactory clarification. Although the juice of the P3–L1 treatment presents no difficulty in the factory, it might be said that its P_2O_5 content is unnecessarily high (K.C.: 31). Therefore, the juices obtained with treatments P2 and P3 without lime and P1 and P2 with lime (K.C.: 21, 22 and 22, 25 respectively) would be preferred in the factory.

Final examination of soil and root systems in the drums after the crop was reaped, revealed the following facts and information:

(*a*) The soil was still in a coarsely-aggregated and well aerated condition and the root systems of the cane appeared to be in no way ' pot-bound '. In unlimed non-phosphated soil the roots tended to be thinner, with less branch rootlets and hair roots being formed. The occurrence of ' club-tips ' on roots in these soils was noticeable and suggests toxic soil conditions.

(*b*) Soil samples taken at a depth of 12–20 in. from the centre of all 24 M0 drums, were analysed for soil reaction and Truog value:

(*i*) Soil reaction, given by $pH_{norm.}$ and $pH_{exchange}$, was 4·3 and 3·4 respectively for unlimed soil and 5·7 and 4·9 respectively for limed soil. As compared with the values 4·6 and 3·9 at the start of the experiment, the unlimed soil has become alarmingly more acid during these 15½ months.

(*ii*) Truog values, averaged for phosphate treatments P0, P1, P2, and P3 gave levels of 16, 23, 23, 33 for unlimed and 14, 16, 20, 26 for limed soil. From this it may be concluded that plants grown on limed soil draw more heavily on the phosphate resources of the soil. It also seems justifiable to conclude that with the use of P1 dosages, the soil will be left, at the end of the crop, as poor in phosphate as it was before and the same dosage has to be given to each subsequent (ratoon) crop in order to prevent yield depression. Only by using larger phosphate dressings may a gradually increasing phosphate status of the soil be anticipated.

RECOMMENDATIONS

It seems advisable to raise the phosphate status of this soil to a level characterized by a Truog value of about 40 p.p.m. Once adjusted at this

level it can be maintained by dressings of 3 cwt. superphosphate (P1) to each subsequent crop. Under adverse soil conditions, restricting the volume of phosphate supplying soil (M1) or the phosphate absorbing ability of the roots (L0), an allowance must be made and a higher Truog value must be aimed at. Spreading the phosphate through the top 12 in. of soil has proved to be the most effective method. Therefore all phosphate needed for the plant cane should be applied in that layer of the furrow at planting time. It does not seem advisable to give all the phosphate needed for subsequent ratoons in the same spot and at the same time, as too high phosphate concentrations in the soil may suppress the first yield. For ratoons, the phosphate should preferably be worked into the soil in a band on both sides of the row and close to the old stool.

The impeding effect of high soil-acidity on the ability of the roots to absorb the phosphate and other soil nutrients, makes it imperative to bring the soil reaction throughout the top 12–18 in. of soil to a permanent pH level of 6·0–6·5. If too large quantities of lime are required to attain this pH in one application, it would be preferable to reach this final pH over a longer period with smaller dressings per cycle.

SUMMARY

(1) A factorial pot experiment is described in which sugar cane was grown in 40 gal. drums to an age of 15½ months. The soil was highly acid and phosphate deficient, belonging to the same batch of soil as that used in the pot test described in Paper II.

(2) The effect of four phosphate dosages on the final phosphate status of this soil (as characterized by Truog values) and on the growth and yield of cane was investigated, in the presence and absence of high lime treatments.

(3) Measurements were made at intervals of stem length, number of tillers and of the phosphate content of leaf samples. After reaping the cane, juice samples and bagasse samples were analysed and a clarification test on eight juices was included. All data were statistically analysed.

(4) The data obtained prove that 'phosphate fixation figures', as determined by certain chemical methods, are misleading when related to phosphate availability to plant roots: concentrated placement of phosphate dosages, which eliminates 'phosphate fixation' greatly, proved to be less effective than the spreading of the same dosages through relatively large volumes of soil.

(5) The experimental results demonstrate clearly that the response to any phosphate dressing below the optimal dosage, depends on the concentration of that phosphate in the soil and on the contact area between absorbing root surface and phosphated soil particles. Therefore, adverse soil conditions necessitate a readjustment of the accepted adequate (Truog) phosphate status of the soil.

(6) The highly beneficial influence of liming the soil on the effect of phosphate dressings is stressed.

ACKNOWLEDGEMENTS

The writer wishes first to acknowledge his indebtedness to the General Manager of the Ste. Madeleine Sugar Company Ltd., Mr. E. Johnson, for

his kind permission to carry out this experiment on the Estate grounds with all the help and facilities from his staff and organization. He also desires to express his indebtedness to Mr. F. Little and the assistants on the Field Research Staff of the same Company for their invaluable advice, technical help and personal supervision throughout the experiments. He also wishes to thank the Chief Chemist, Mr. P. E. Knox, for providing the juice analysis data. Finally, he wishes to acknowledge the help of Mr. N. O. Schmidt, Sugar Technologist at the Imperial College of Tropical Agriculture, who conducted the clarification tests on the juices and gave his kind assistance in judging the results.

(*Received July 1954*)

REFERENCES

DILLEWIJN, C. VAN (1952). *Botany of Sugar Cane,* 1st Ed., 173–179 and 236–243, Chronica Botanica Co., Waltham, Mass.

HARDY, F. (1947). ' Effects of increasing phosphate dosages on the utilisation of nitrogen ', *Trop. Agriculture Trin.*, **24,** 9–18

POTTER, J. A. (1948). ' Fertilizer field experiments with sugar cane in phosphate deficient soils in south Trinidad ', *Trop. Agriculture Trin.*, **24,** 94–108

SCHMIDT, N. O. (1953). ' The settling of defecated sugar juices ', *I.S.S.C.T. Proceedings 8th Congr.*, 729–741

SCHROO, H. (1953*a*). ' The fertility of sugarcane soils with special regards to phosphate ', *I.S.S.C.T. Proceedings 8th Congr.*, 116–123

— (1953*b*). ' The use of pot tests in research on the fertility of sugar cane soils ', Paper I. *Trop. Agriculture Trin.*, **30,** 109–205. Paper II. *ibid.*, 206–215

TURNER, P. E. (1940). ' Field experiments on sugar-cane in Trinidad ', *Annu. Rep. Sugar Cane Investigation Committee,* p. 236

Book Reviews

INSECTICIDES AND COLONIAL AGRICULTURAL DEVELOPMENT

Edited by T. Wallace and J. T. Martin. Butterworths Scientific Publications, London, 1954. 161. *pp.* (illus.) 30*s*

This attractively produced publication consists of the Proceedings of the Sixth Symposium of the Colston Research Society, held at the University of Bristol in March 1953. It contains 16 papers, and reports of the discussions arising therefrom, on a wide range of problems from many different countries.

W. J. Hall (The Importance of Crop Protection to the Colonies and its Relation to Agricultural Development) gave a brief review of crop production in the colonies and an estimation of the losses caused by insect pests. It may surprise many people to learn that only 14 out of the 38 British colonies employ an Entomologist in their Department of Agriculture, and even though some of the larger colonies employ more than one, there is a total of only 29. These few entomologists have such a wide range of duties to perform that it is seldom that they can devote their time to making a thorough study of the life-history and habits of a pest, without which the efficient and economic use of insecticides is severely handicapped.

C. B. Symes (Some Observations on Colonial Insecticide Research) outlined the work on insecticides now in progress and stressed the need for more fundamental research.

S. Callaway (The Control of Locusts by Insecticides) dealt chiefly with the application of insecticides from aircraft, both against hoppers on the ground and flying swarms, and G. Bouriquet (La Lutte antiacridienne dans les Territoires français d'outre mer) gave an account of the control measures undertaken in the French Sudan, Cameroons and Madagascar.

E. O. Pearson (The Control of Pests of Cotton in Tropical Africa) said that so far the only large-scale use of insecticides against cotton pests in Africa has been the control of jassids on the irrigated cotton in the Gezira area of the Sudan, which has been strikingly successful for several reasons that are mostly inapplicable to other pests and areas. First the jassid lives an exposed life; secondly if the original immigration that would give rise to an outbreak is controlled over a large area reinfestation does not occur; thirdly there is no danger of rain after spraying; lastly the yields and quality of the Gezira cotton are both high, and even a small increase is therefore economic. He considered, however, that chemical control might be justified on a commercial scale against *Lygus* in Uganda and American bollworm in eastern Tanganyika.

K. S. McKinlay (The Design of Insecticide Field Trials on Cotton in Uganda) gave an account of experiments with insecticides designed to assess the amount of damage to cotton caused by *Lygus*.

G. Swaine (Insecticide Investigations of Crops in East Africa) described experiments in which five applications of 10 per cent DDT dust plus 3 per cent BHC against American boll-worm increased the yield from 13 to 1,483 lb. of seed cotton per acre. The coffee bug, *Antestia*, is also now successfully controlled by DDT, and BHC and Aldrin have shown promise against soil inhabiting insects attacking wheat and sugar cane.

M. J. Way (A Problem of Insecticides and Biological Control in East Africa) related how in Zanzibar control of the leaf nesting ant *Oecophylla* with BHC resulted in successful control of the scale insect, *Saissetia* sp., on clove trees, but at the same time caused a greatly increased nut-fall in adjacent coconut palms due to multiplication of the Coreid bug *Theraptus*, which had previously been preyed upon by *Oecophylla*.

J. Bowden (Crop Protection Problems in West Africa) dealt mainly with borer pests of cereals in the Gold Coast. Fair control of *Sesamia* and *Busseola* has been obtained with BHC and DDT dusts ' applied with that much-maligned piece of equipment—a cigarette tin '. The most promising line of control of the destructive sorghum midge lies in the recent discovery of a resistant variety of sorghum, though insecticide trials will shortly be started.

R. G. Fennah (The Role of Insecticides in the Agricultural Development of the British Caribbean Territories) considered that, apart from the control of frog-hopper on sugar-cane estates and the control of parasol ants, there was little prospect of any greatly extended use of insecticides in these colonies in the foreseeable future. The low yields now obtained are, he believes, due far more to inefficient agronomy consequent upon a lack of basic knowledge of the problems of the terrain and climate, than to the losses caused by insects.

J. W. Munro (Losses Caused by Insects in Crops During Storage and Transit) in a general review of the increasing importance of this problem, emphasized that a considerable amount of knowledge about the control of stored product pests was available, but only too often it was not being used.

Sir Thomas Dalling (Insect- and Tick-transmitted Diseases of Livestock) gave a general account of the protozoan parasites and J. Carmichael (The Control of Insects of Veterinary Importance with Special Reference to the Tsetse Fly) included an account of a successful experiment in Tanganyika where 10,000 acres were sprayed with a DDT aerosol from aircraft. Seven applications each giving an average of a quarter of a pound of DDT to the acre reduced the population of *Glossina swynnertoni* by 97 per cent, of *G. morsitans* by 98·5 per cent, and of *G. pallidipes* by over 99·9 per cent.

H. E. Harbour (The Control of Ectoparasites of Livestock) referred to the earlier methods of control by arsenical dips and the great advances that had been made when DDT, BHC and Toxaphene became available. He dwelt on the problem of the development of resistance to insecticides and stressed that it was important to continue the search for new ones, particularly others besides chlorinated hydrocarbons, so that alternative weapons would be available if further cases of resistance developed. He also discussed various methods of applying insecticides to livestock besides the old-fashioned dipping which, however, is still the best method on a large scale, if it is efficiently carried out.

H. G. H. Kearns (Spraying Technique and Machinery) emphasized that successful application of insecticides involves a knowledge not only of the insecticide and the machinery for applying it, but also of the life history of the pest, the agronomy of the crop, and the mentality of the operators. He described the difficulty of designing spraying and dusting equipment to meet everyone's demands and regarded it as essential to reduce the number of designs to a minimum, to secure cheap and efficient manufacture. It was not, however, possible to comply with the frequent request for a long-lasting absolutely reliable, unbreakable sprayer to cost not more than 10 shillings.

E. Holmes (Insecticide Manufacturer's Research and Supply Problems) discussed the question ' from the other side of the hill ' and referred to the difficulties and cost of producing a new insecticide. When the cost of all the inevitable failures is taken into account, this is probably in the neighbourhood of £500,000. He also referred to the increasing and welcome co-operation between manufacturers and official research workers.

The discussions on many of the foregoing papers included references to the difficulties of applying available knowledge on insecticidal control of pests to the conditions of peasant agriculture. To increase the deplorably low yields from peasant holdings, first by improved agronomy and subsequently, when necessary, by pest control, is perhaps the most pressing problem that faces Colonial Agricultural Departments. If this problem is not solved, though the reviewer is reasonably confident that it will be, either there will be an ever increasing risk of serious famines or peasant agriculture will have to go. And that would be a great pity.—T.W.K.

THE COCONUT RHINOCEROS BEETLE (*Oryctes rhinoceros*) WITH PARTICULAR REFERENCE TO THE PALAU ISLANDS

J. Linsley Gressit, Entomologist, Bernice P. Bishop Museum. Bulletin No. 212 of the Bernice P. Bishop Museum, Honolulu, 1953. viii + 156 *pp.*, 50 figs., 310 refs.

In recent years there has been a considerable spread of the coconut rhinoceros beetle in the islands of the Pacific, some of the latest accidental introductions having been to New Britain and Palau about 1942, Tonga Islands about 1951, and Fiji in 1952. The beetle is probably native to the southern mainland of Asia, where it is more or less kept under control by various factors, many of which appear to be lacking in the islands: consequently it presents a serious threat to coconut cultivation, on which the economy of several of the islands largely depends. The larvae develop in dead wood, compost and other types of rotting vegetable matter, but the dead trunks of coconut palms are the favourite situations. The recent epidemic of *Oryctes* in the Palau Islands is an aftermath of the war, for the numerous coconut palms killed by gunfire afforded abundant breeding places.

This bulletin includes descriptions of all stages of *O. rhinoceros*, an account of its biology and ecological relationships in the Palau Islands, an evaluation of the damage done by the adults to living coconut palms, an account of the insects and other animals associated with the beetle in both its breeding and feeding sites, and a discussion of control measures. Though

the latter contains no startling original suggestions, for sanitary measures to reduce breeding sites are still regarded as the most effective, this very full compilation of our present knowledge will form an invaluable starting point for the intensive research on this pest which, it is understood, has recently been proposed. It will also be useful to workers in Africa where other species of *Oryctes* occur the habits of which are, so far as is known, not very dissimilar to those of *O. rhinoceros*.—T.W.K.

PRINCIPLES OF SUGAR TECHNOLOGY

Edited by Dr. Pieter Honig. Elsevier, Houston, 1953. xxii + 767 *pp.* $15·00 U.S.

'Principles of Sugar Technology' is a large and expensive book. It comprises 18 chapters written by 13 different people closely associated with sugar chemistry and the sugar industry, the whole being welded together by Dr. Honig who himself contributes three of the chapters. After reading the book the idea presents itself as to how much better it would have been had it been written by one (preferably by Dr. Honig himself) or two authors. The preface sets out clearly Dr. Honig's aims for the book, which are excellent, but unfortunately, all the chapters do not live up to these ideals—in some the principles of sugar technology certainly receive second place. Almost inevitably with so many authors writing on different facets of the same general subject, there is much overlapping and repetition. Intensive editing might have avoided this, but it would have been a heavy and difficult task.

The book is in two parts, the first entitled 'Physical and Chemical Properties of Sugars and Nonsugars', containing 11 chapters, and the second 'Purification of Technical Sugar Solutions' of seven chapters in length. The book need not have been quite so long and therefore perhaps not quite so expensive. The inclusion, in certain chapters in part one, of long tables of physical properties of sugar and sugar solutions already available in standard analytical works regularly used by sugar technologists, was unnecessary. The chapter on colour and coloured nonsugars, although excellent in isolation would seem to be excessively long in its present context; too much space is directed to colour measurement, a subject very adequately dealt with in other standard reference books. Similarly, Chapter 3 contains unnecessarily detailed methods of sugar analysis which are readily available elsewhere. Again, in Chapter 7 the full details of methods of lipid analysis given seem out of place. Furthermore, in the same chapter, the photographs of parts of a cane wax factory are not very illuminating and hence an unnecessary expense. On the other hand, crystallization is completely omitted and subjects like the decomposition of reducing sugars by alkali or by acid and the inversion of sucrose are but cursorily dealt with, despite which, in the latter topic, a diagram depicting the rate of inversion of sucrose is repeated at least three times. In the second part of the book there is also much repetition. For example, Stokes' law in relation to settling juices is discussed twice (pp. 524 and 563), once by the author of the chapter on fundamental reactions of the clarification process and once by a different author writing on the technology of the clarification process.

In contradistinction to the excessive length of the book, the index is too slight. Students who use the book would be able to do so with better advantage if both the author and subject index were made much fuller.

The book is attractively presented, but a few misprints have escaped the proof reader, for example, mis-spelling of British in the list of contributors and the use of wrong type in setting up the symbol B.H. 10(12).

On the whole, however, there is little to criticize of the publisher's work and despite its defects, or rather the improvements that need to be made, ' Principles of Sugar Technology ' contains a wealth of information, some of it of great interest and usefulness, so that it is a ' must ' for all practising sugar technologists and for students of this subject.—L.F.W.

SUKUMALAND. AN AFRICAN PEOPLE AND THEIR COUNTRY

D. W. Malcolm. Oxford University Press, London, 1953. 224 *pp.*, 32 illus. with 9 maps, 14 plans and diagrams. 30*s*

To anyone who is or has been concerned with the development of primitive agricultural communities in the tropical world this book provides fascinating reading. It embraces in its scope a fundamental study of those basic factors—the people and the land—a knowledge of which is essential if developments are to be planned on sound foundations. The problems of adjusting the balance between population and land, of effecting improvements in agricultural methods and practices, of proper land utilization, and of increasing production and improving living standards, are all too familiar to those whose work lies in areas such as Sukumaland. But all too frequently development schemes have been launched without adequate knowledge and without due appreciation of such important considerations as, for example, the social structure of the people and customary systems of land tenure and land usage. In Sukumaland it is clear that no such mistake has been made; over a number of years the author and his colleagues have studied closely all aspects of life in the Federation, and the results of the work are now permanently recorded in this volume; thus after a general description of the country, and of the main ecological features, there is a detailed account of the people and the land which embraces such aspects as the relationship of hereditary authorities to the land, social structure and inheritance, land use, problems associated with livestock and local law and custom. Legislative and administrative functions of Local Native Authorities are also described before the main development problems are analysed and a description given of the ways in which these problems are being tackled by a special development team responsible for the control of all reconstruction and development work throughout the area.

The Appendix to the book gives useful, practical information on the construction of surface water catchment works and on the soils and vegetation of Sukumaland.

Above all, the book provides a valuable illustration of the advantages, indeed of the essentiality, of continuity of effort. The author has spent altogether some 12 years in Sukumaland and was thus able to undertake these detailed studies in a way which is not possible under a system, today all too common, of frequent changes of staff from district to district.—A.B.K.

FARMING RECORDS AND ACCOUNTS

JAMES WYLLIE. Butterworths Scientific Publications, London, 1953. 310 *pp.* 30*s*

This book is the first of a new series of monographs on scientific agriculture. If the Wye College Series succeeds in maintaining the standard of its first number it will form a very valuable contribution to agricultural literature indeed. In addition to the high quality of the content, the printing and presentation are altogether admirable.

Mr. Wyllie can write on his subject with the authority commanded by few others. For 30 years, during which British farming has experienced extreme changes of economic climate, he has worked primarily on farm accounts; everything he has to say, whether on the practicability or mechanics of accounting, whether on the usefulness of efficiency factors or budgeting, is the fruit of longer and more concentrated professional experience of the subject than most readers can boast.

But his book contains something more fundamental than the summary of a lifetime's experience. It is that accounts are of immense value in assisting the management of the particular farm on which they are kept but that they, and much other numerical data, are of limited usefulness in diagnosing the economic weaknesses and opportunities of any other farm. Mr. Wyllie quotes the change he achieved, in co-operation with his old friend the manager, at Wye College farm; by keeping and really using accounts, average profits of only £115 a year in the '20s were increased to an average of £1,390 a year in the '30s. The fact that the innovations on the College farm did not set off an agricultural revolution in Kent resulting in profits 10 times as high as previously proves the point. The particular combination of innovations were specially selected to solve the College farm problems; they were not a magic recipe for any and every other farm.

Although the author is too forebearing to say it, the indiscriminate comparison of farm with farm and the consequent attempts to devise universal rules to make cost figures comparable brought costing and accounting largely into disrepute in the early days of agricultural economics. In this reviewer's opinion it was a major professional disaster, the effects of which have spread even to the most distant outposts of the Commonwealth. The agricultural officer who as a student has never undergone the discipline of accounting and has therefore little knowledge of the processes involved and little appreciation of the usefulness of the results obtained has very limited means at his disposal of improving the agriculture on his station or in his district. He is rather like a blind man, but one who cannot imagine the advantages of sight.

It is sincerely hoped that Mr. Wyllie's book, by the vigour and clarity of his arguments, will add the necessary power to a tool that has been misused or unused for so long.—A.L.J.

ROYAL AGRICULTURAL SOCIETY OF KENYA QUARTERLY JOURNAL

No. 1, February 1954. P.O. Box 500, Nakuru, Kenya. Price 1*s* per number

In a foreword to this new Kenya venture, the Member for Agriculture and Natural Resources states that, in addition to existing publications,

' there is obviously a need for more popular articles on a wide variety of subjects which will help to keep the farming community in touch with research in progress and to get the results of that research to the public at the earliest opportunity '. It is to be hoped that the journal will receive enough support and be sufficiently careful to avoid overlapping with other publications to achieve these aims. Articles in the first two numbers on milk recording and various aspects of pasture production set a tone which, if maintained, should enable it to do so.—G.B.M.

TITLE-PAGE AND CONTENTS LIST FOR VOLUME 31

The title-page and contents list of Volume 31 of this journal, of which this is the last number, will be issued with our number of January 1955 for the benefit of those who wish to bind it to complete the annual volume.

Recent Publications of The Imperial College of Tropical Agriculture

Studies in West Indian Soils, XII: The Agricultural and Forest Soils of St. Lucia, by F. HARDY and G. RODRIGUES. 5*s*

Studies in West Indian Soils, XIII: The Agricultural Soils of St. Kitts-Nevis with Notes on Statia (Dutch), by F. HARDY and G. RODRIGUES. 5*s*

A Report on Cacao Research, 1945–1951. 132 *pp.* fully illustrated in colour and black and white. 25*s*

A Report on Cacao Research, 1952. 8*s*

A Report on Cacao Research, 1953. (in the press)

Flora of Trinidad and Tobago: This Flora, which has been issued irregularly in parts since 1928, is a compilation of the work of many authors. The early parts, mainly by R. O. WILLIAMS, were edited by the Department of Agriculture of Trinidad and Tobago, but since the end of the second world war editing has been taken over by the Botany Department of the Imperial College. The Flora may be obtained either from the Department of Agriculture or from the Imperial College. The following parts have been published :

Volume I Ranunculaceae to Araliaceae complete in eight parts and index. 26*s* 6*d*

Volume II Part 1. Rubiales. 2*s*

Part 2. Asterales to Primulales. 3*s* 6*d*

Part 3. Ebenales to Polemoniales (in part). 5*s*

Part 4. Polemoniales (in part). 5*s*

Part 5. Scrophulariaceae to Acanthaceae, in the press.

Further parts are in preparation.

These and other publications can be obtained from the Library and Publications Department, Imperial College of Tropical Agriculture, Trinidad.